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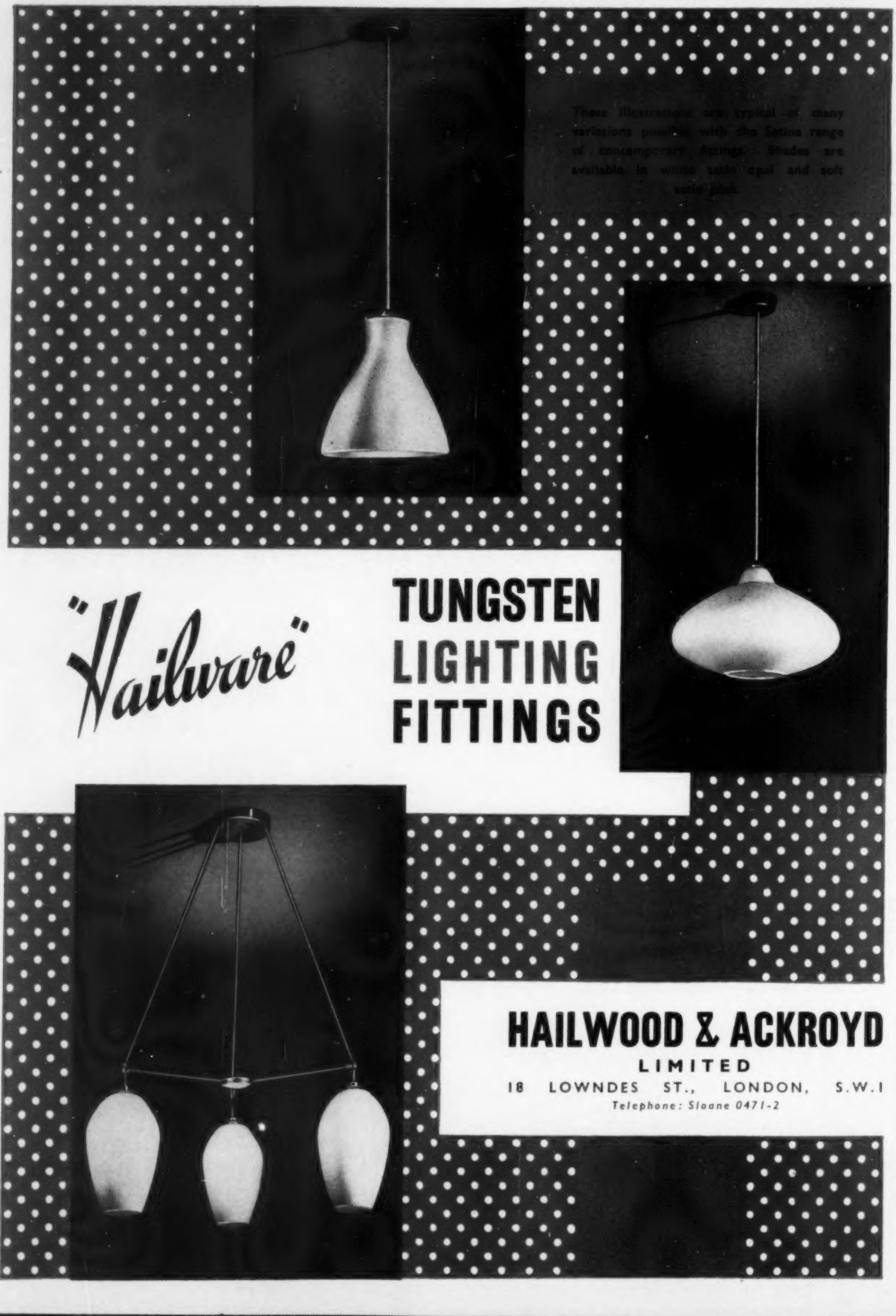
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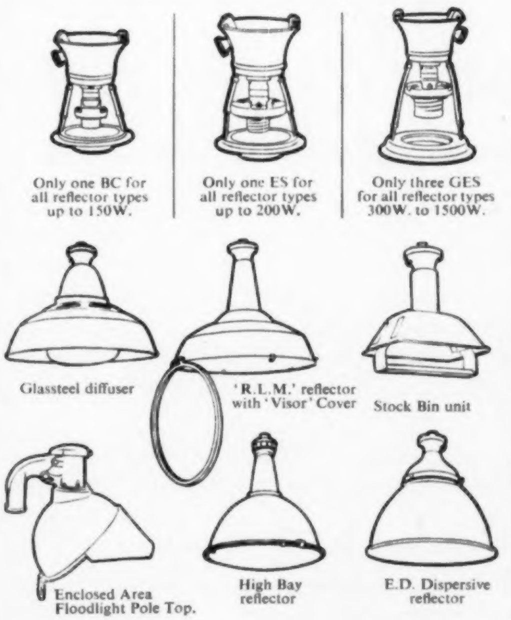

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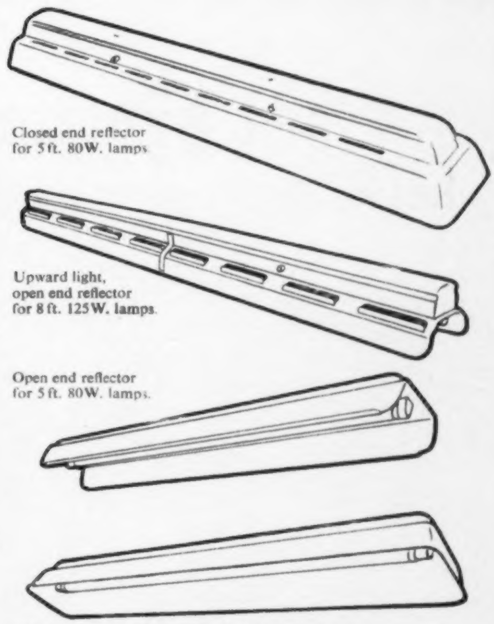

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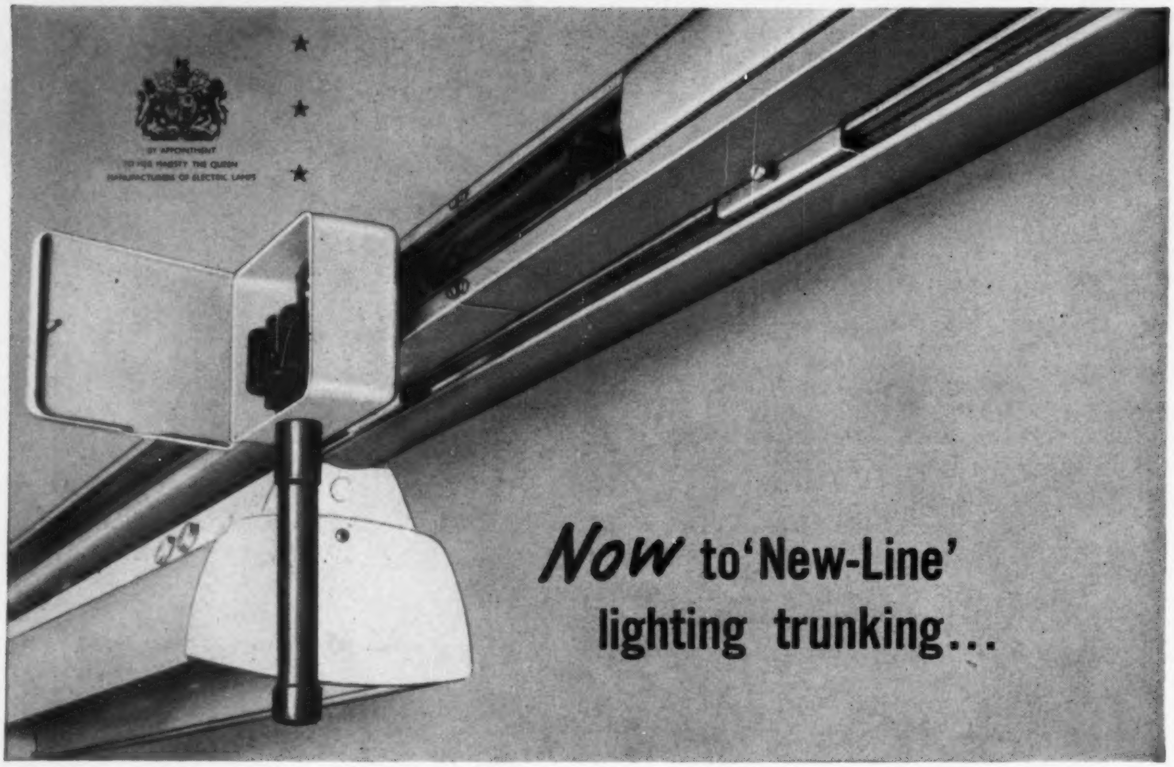
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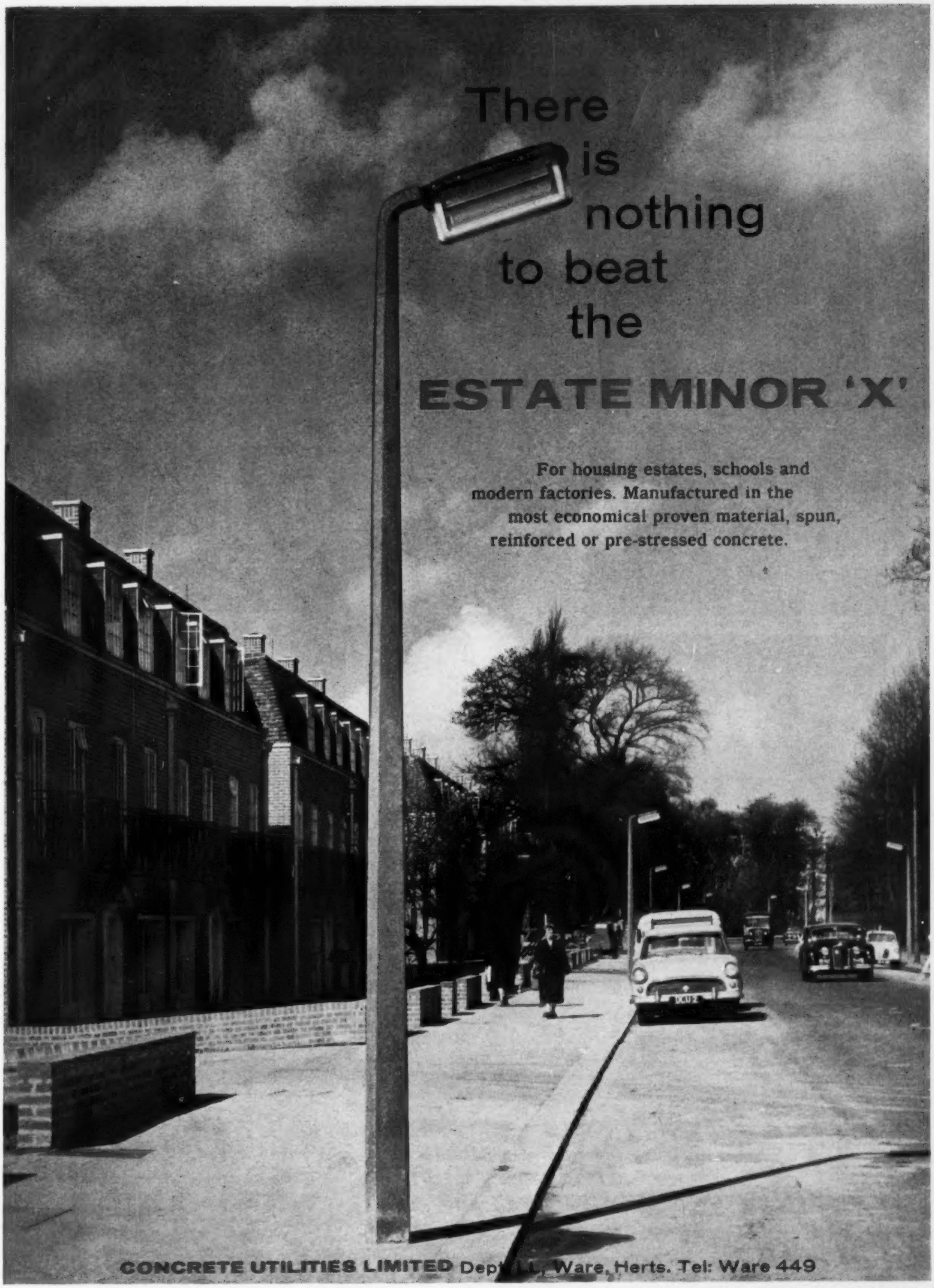
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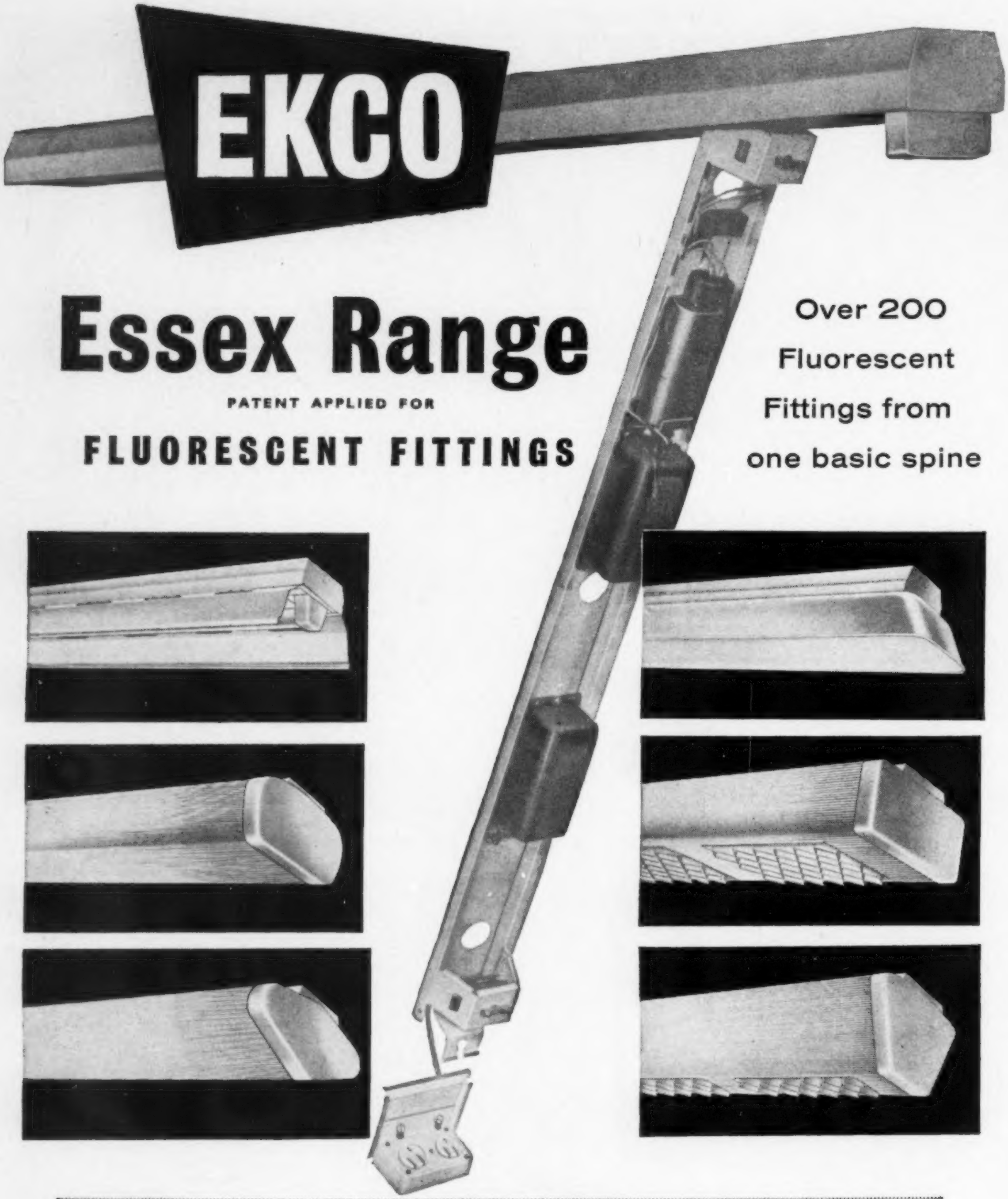
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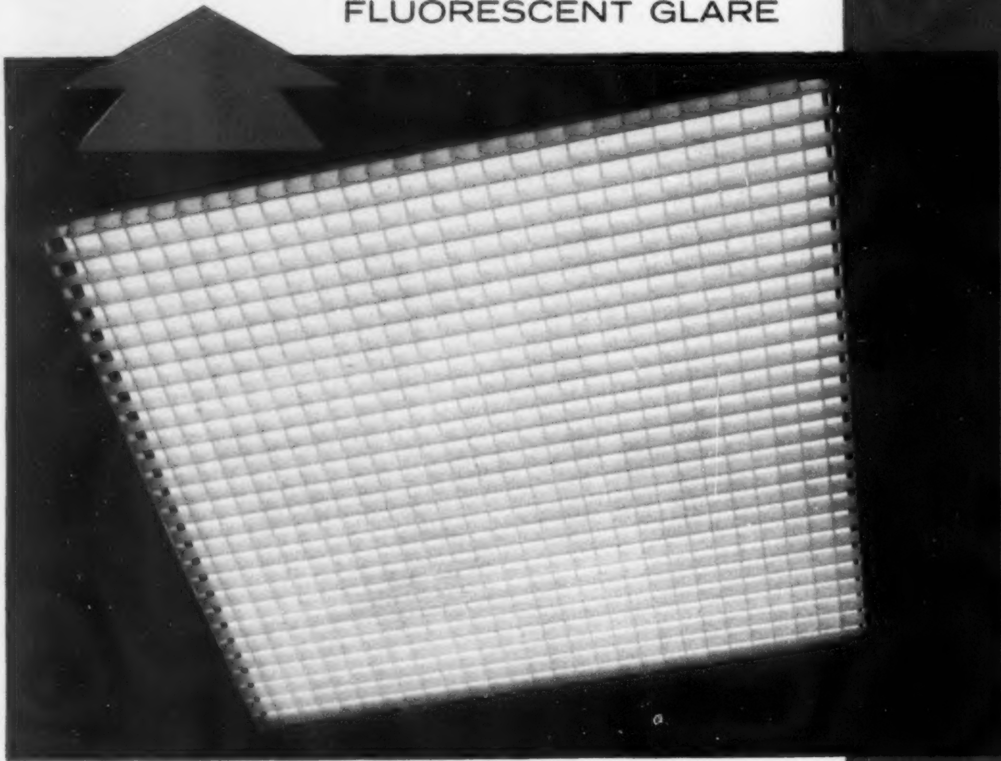

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Light and LIGHTING

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contents

Shop Window Lighting

SHOP window lighting at its best to-day can certainly be marked "very good" or "excellent." Modern lighting equipment and techniques give to the true artist in merchandise display lighting sufficient resources for the achievement of results which do not consist only in attracting the potential shoppers' gaze and revealing the offered goods adequately when they are looked at, but include the creation of scenes aesthetically pleasing in themselves—thus adding to the street amenities. Unfortunately, such good results are by no means always achieved. It is easy to attract attention merely by making a shop window a blaze of light, but this effect may be quite unpleasing and sometimes unrevealing also. Nevertheless, a relatively heavy lighting load is justifiable for many shop windows and, when this is utilised to the best advantage, the results are likely to be rewarding to all concerned. In towns large and small—in our own country and in others—fine examples of the art of shop window lighting are to be found, and it would be difficult indeed to say where are the very best examples. No matter. What is important is that there should be much wider emulation of the good in this field, and it should not be thought that the cost of achieving very good shop window lighting puts it outside the pocket of the small shopkeeper.

Notes and News

ON February 16 the fifth Trotter-Paterson Memorial Lecture of The Illuminating Engineering Society was given by Professor Sir Solly Zuckerman, CB, FRS, head of the Department of Anatomy at the Medical School, University of Birmingham, and Secretary of the Zoological Society, in the lecture theatre of the Royal Institution which was well filled by members of the Society and their friends. In the chair was the President, Mr. C. C. Smith, who briefly recalled the origin of the lecture and welcomed particularly members of the families of the two outstanding lighting engineers whom it commemorated.

Sir Solly began by emphasising the difficulty of dealing with the influence of light on living matter. Living matter itself was extremely difficult to define. Whatever the definition adopted, however, it was clear that solar energy provided the materials of life and was essential for its maintenance. This energy was subject to cyclical variations, both diurnal and seasonal.

In any discussion of the subject, the process of photosynthesis and the formation of chlorophyll in green plants were fundamental. There was a living food chain and the seasonal variation in the trapping of energy by the land plant or by the marine plankton was the background of the annual cycle of life. This was well illustrated by the behaviour of the basking shark which fed on plankton as long as this was plentiful but hibernated at the bottom of the sea when the supply of plankton diminished owing to lack of light.

Next the lecturer dealt with the control exercised by light on a very important seasonal variation in the life cycle of animals, the breeding season. The polar bear, which in the northern hemisphere had its young only in November, if kept in a menagerie in Australia would transfer its breeding time to the corresponding season in the southern hemisphere. Unless a species could make this kind of adjustment, transfer from one hemisphere to the other resulted in its disappearance in the new environment.

Another very interesting phenomenon was the migration of birds. Although this had been observed for centuries, it was only comparatively recently that a Canadian zoologist had discovered that most migrations were triggered off by variations in the intensity of the light. The instinct to migrate was dependent on the state of the reproductive organs and this, in turn, depended on the light cycle. If birds which had been prevented from migrating until they ceased to show any desire to do so were artificially illuminated, the reproductive organs were reactivated and the instinct to migrate was revived.

Light was the functional stimulus for bringing the reproductive organs into an active condition and in fact this was the basis for the use of artificial illumination to encourage egg production at a season when it would normally be low. Ferrets, too, could be caused to breed out of season by exposing them to quite a low illumination. The lecturer mentioned two lumens per square foot as sufficient. A blind ferret, however, would not react in this way. It seemed, therefore, that light acting on the retina of an animal's eye influenced its physiological mechanisms. The way in which this occurred was still unknown in spite of much research. The link between the pituitary gland and the reproductive organs was well known, but the link between the eye and the pituitary gland remained a mystery.

The lecturer then showed a slide illustrating the processes by which light entering the eye caused a stimulation of the visual cortex in the brain and so produced the sensation of vision. Many experiments had been carried out with the object of finding a possible pathway to that part of the brain which regulated most of the physical functions of the body, but without success. There was the further difficulty that the part of the pituitary gland which was connected with the brain was not the part producing the hormones.

In conclusion Sir Solly described an hypothesis which until recently had been accepted as a possible explanation of what took place, but he said that this had now been disproved. Nevertheless it provided a good illustration of the difficulties involved in trying to understand the very potent effects which light had on physiological mechanisms.

A vote of thanks to the lecturer was proposed by Professor W. D. Wright, who referred to the Society's Golden Jubilee and to the importance of the contribution made by lighting to the well-being and efficiency of mankind. The seconder was Mr. D. L. Tabraham, who said that Sir Charles Wheeler, a week before, had emphasised the contribution of light to the joy of living; the lecturer had shown that indeed light was largely responsible for the fact that we lived at all.

APLE Conference

The annual conference of the Association of Public Lighting Engineers is to take place in Aberdeen in September, between Tuesday, 15th, and Friday,

18th. Papers will be presented in the Music Hall, which will also house the usual display of street lighting apparatus. Lamp columns and mobile equipment will be on show in Golden Square and North Silver Street respectively.

We seem to remember that when it was announced last year that Aberdeen was to be venue for the 1959 conference some doubts were expressed as to the amount of suitable accommodation available in that city for such a large number of delegates. It would seem that those doubts were well founded as the Secretary of the APLE, Eric Evans, has apparently found it necessary to send out a circular to the effect that the larger hotels are already fairly well booked and advising would-be delegates to save time and postage by seeking rooms in the smaller hotels, guest and apartment houses. An accommodation list can be obtained from Mr. Evans and those who wish to attend the conference are advised to book their beds without delay.

The programme of papers to be presented at Aberdeen is, with all respects to the individual authors the excellence of whose contributions we do not doubt, pretty thin. In four days there will be five papers. The remainder of the time is taken up by inspection of the exhibits, social functions and a tour of Deeside—and, if you can get away with it, to see Deeside in September is sufficient excuse for going to Aberdeen. The five papers include, the presidential address by Mr. Ronald Parker, "Craftsmanship in public lighting," by L. C. Rettig; "A planner looks at public lighting," by J. E. Barlow, Director of Town Planning for Aberdeen; "Some practical aspects of street lighting column and lantern erection," by A. V. McKenzie; and an address "Fifty years of lighting," by Charles Smith, President of the IES and a past-president of the APLE. The latter is included in recognition of the Golden Jubilee of the IES. It is not exactly the sort of programme that will attract the waverers who may feel Aberdeen rather a long way to go; but if it helps anyone at all we can say from experience that Aberdeen is a jolly nice place.

Street Lighting Columns

Those who have enjoyed airing their views on street lighting column design during the last few years will no doubt welcome the opportunity provided by the Aluminium Development Association to take part in a competition for the design of aluminium columns. The competition is open to any individual or group of people and is intended to encourage the evolution of good designs taking especially into account æsthetic appearance, economy of construction, and (naturally) the advantages of aluminium. Designs may be submitted for Group A and/or Group B lighting and the prizes are £250 (1st), £100 (2nd), £50 (3rd) and a student's prize of £75. The assessors are Lionel Brett, Sir Alfred Pugsley and Sir Gordon Russell—a team that will be hard to satisfy but whose commendation would be valued. Full details of the competition and entry form can be obtained from the Secretary, Aluminium Development Association, 33, Grosvenor Street, London, W.1. The closing date is July 1: intending entrants should lose no time.

IES Monographs

A few months ago the IES announced some changes in its publication policy having in mind particularly the considerable amount of highly specialised research now in progress and also the practical outcome of the IES Technical Committee.

The first Technical Report, dealing with lighting in corrosive, flammable and explosive situations, was published at about the same time and we understand that it met with an immediate success and has reached people in many industries faced with these problems. Other reports from the Technical Committee on other subjects will come along from time to time.

The other specialised contributions, some of which have in the past been published in the Transactions but many more of which have never seen the light of day, are to be published as IES Monographs. These contributions will form a valuable source of advanced lighting knowledge and provide a unique service to members of the society and to the industry. In addition they will provide a means of publication which has not previously existed; publishing these days is a very expensive business and much as the IES has wished to publish original work it could not afford to do so. The idea of publishing Monographs in a limited edition which can be purchased by those who are interested in these fundamental subjects is a good solution to the problem and should be welcomed by both authors and readers. The value of some of the subjects dealt with may not be immediately apparent to the practising lighting engineer but we would remind them that much of present-day practice is based upon fundamental work which was done many years ago. If members of the Society can help to make this venture a success then they, the industry and the Society will benefit in the long run.

Monograph No. 1 is now available and contains a paper by J. A. Lynes on "Inter-reflection and Flux Distribution in Lighted Interiors" and describes a method for calculating the distribution of light due to multiple reflections inside a room.

Both Monographs and Technical Reports are published in the same format as the Transactions and cost 5s. each, by post 5s. 6d., from the IES Secretary, 32, Victoria Street, London, S.W.1. Those wishing to receive all such publications as they appear may place standing orders.

The centre-piece at the recent Electrical Engineers Exhibition was an internally illuminated three dimensional version, designed by Beverley Pick, of the IES Golden Jubilee symbol (designer Gordon House). Mounted above the centre stands and over the gangways, the " hand " itself was nearly 18 ft. high and must have drawn the attention of the thousands of visitors at the exhibition to the IES Jubilee.

Electrical Engineers Exhibition, 1959

By Derek Phillips, A.R.I.B.A.

A critical review of the lighting exhibits by an architect who has specialised in lighting and whose appraisal and criticism of any item of lighting equipment may be based on a different point of view from that of the lighting engineer—or manufacturer—and is therefore the more welcome.

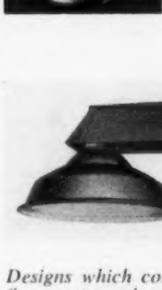
It is probably inevitable in the growth of any exhibition that there comes a moment when the first flush of enthusiasm is spent and people begin to ask themselves whether it is all worth it. It was rather unfortunate that this should have coincided with the Jubilee year of The Illuminating Engineering Society, so that instead of being a triumphant year for development in the lighting industry, the Electrical Engineers Exhibition, 1959, was decidedly "seedy." The exhibition was ponderous, the grouping of exhibits was as poor as in previous years, and there was an air of lethargy about the stands of many lighting equipment manufacturers. I believe that this will only be a phase through which the exhibition must pass, an indispensable aspect of adolescence, and that if the British electrical industry is to remain healthy, the exhibition must continue on to the brighter fields of a new Hanover.

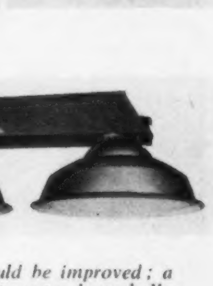
The exhibition had an incongruous beginning in the forecourt of the Warwick Road entrance—a "diesel electric locomotive with 19th century styling"; fortunately this was not representative of trends within the exhibition itself, where on the whole the gains made in last year's "design" were maintained; it was comforting to see that more than one design which had been criticised in these columns last year, had been reconsidered and improved.

As design in general improves, the "bad" becomes more apparent. It is rather like redecorating a house; the more you do, the more you see there is to do, and there is plenty to do in the field of design in the electrical industry. Poor designs which would have escaped unnoticed two or three years ago but which are now much more noticeable, are two bulkhead fittings by Wardle, one using a fluorescent source, and the Benjamin model "50" blended light unit for tungsten and mercury lamps.

There were a number of "come-ins" to the exhibition, but these were on the whole rather less interesting than in previous years. The central feature of the exhibition, the Jubilee symbol of the IES pointed to a shortage of funds; one wonders how it compared in cost to the spectacular central feature to last year's "Furniture Exhibition" by Mischa Black which seemed to express the spirit of adventure in lighting rather better.

Atlas Lighting put on a display of light and sound called "Aurama," a "dynamic" display of "loud" stereophonic music from Tchaikovsky's "Fantasy on the Tempest" heard against a stage setting on which the only actor is light itself, an actor who from Woburn to Greenwich has always seemed to me a little inadequate. The GEC put on a colour film of the installation of the floodlighting of Niagara Falls. In addition there was a "shopping arcade" in which ten lighting equipment manufacturers experimented with shop window lighting techniques. A number of these were of interest, and as each manufacturer was set a rather different problem it would be invidious to select a "winner." Courtney Pope were perhaps most fortunate in the choice of their display, that of furnishing fabrics from Selfridges set dramatically against a changing illuminated plastic background with the addition of either "dynamic" moving spotlights or low voltage lamps used in coloured reflectors. The "dynamic" theme was carried on by Atlas Lighting in a thoughtful scheme (also low voltage) for a typical Chelsea shop window, individual objects being highlighted in sequence, an effect which would almost certainly attract the late night window shopper. The A.E.I. Lamp & Lighting Co. made the most of a fine display of furniture and fabrics from Dunns of Bromley, in this case leaving it to the visitor to choose the type of lighting which he found to be most visually satisfactory. (I am wondering whether there was an electronic memory, or perhaps a "little man," making the most of this "subjective research".) The least successful effects were achieved by the various forms of louvred or luminous ceilings employed; the conditions proved quite





Designs which could be improved; a fluorescent and a tungsten lamp bulkhead fitting and a blended light unit.

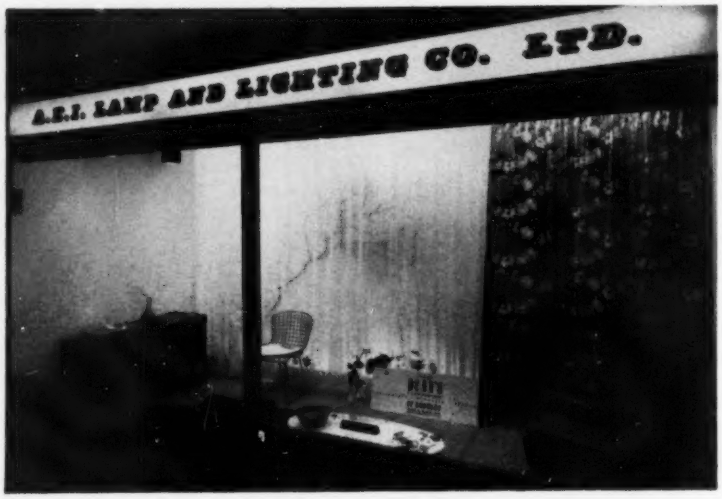
unsuitable for these methods of lighting.

If this was an "economy" exhibition this influence was most clearly seen in the exhibition stands themselves which were more simple and in many respects better than in previous years. With the development of the technique of display stand design, which has probably reached a higher standard in this country than elsewhere, it is evident that the more one tries to achieve a "different" or "unique" design, the more the "stand" merges with the general chaotic background, so that the more simple the stand the more it attracts. Representative of this new approach were the stands of Harris and Sheldon, and Siemens Edison Swan, both of which enabled a visitor to see the products on display with ease, and both provided ample space to "sit" and discuss, a considerable advantage. It was rather unfortunate that in the case of Harris and Sheldon, this particular approach was unsuited to the display of "Paragrid," which whilst most impressive from a distance, was too high to show up to advantage when on the stand itself—an inherent weakness in louvres having a cut-off at as little as 40 degrees—similar installations in America would be 52 degrees at least.

Lamp development

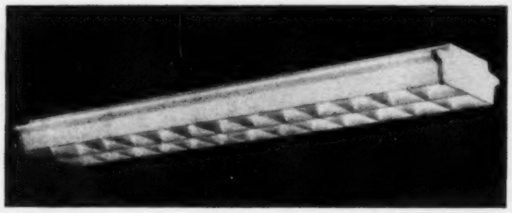
The Philips stand was again devoted to developments in lamps rather than lighting, and the stand itself made interesting use of the space available to feature some of the more dramatic effects which can be achieved. There was in fact little new, and this maintained the impression gained in previous years that development in lamps is at present in a period of refinement and improvement after the major break through with fluorescent and discharge lamps some years ago. Electroluminescence still remains an attractive toy but it is to be hoped that the research laboratories will eventually discover the key to its enormous latent possibilities. Philips featured their 8-volt 50-watt lamp for 8mm. cine projectors which gives a light output equivalent to a mains voltage 500-watt lamp. The low voltage idea was further demonstrated by the 28-volt 20-watt lamps for shop window displays which were also seen in a number of fittings in different parts of the exhibition. There was also a reflector version of the colour corrected mercury lamp.

Crompton Parkinson reiterated their claim made during the year that their

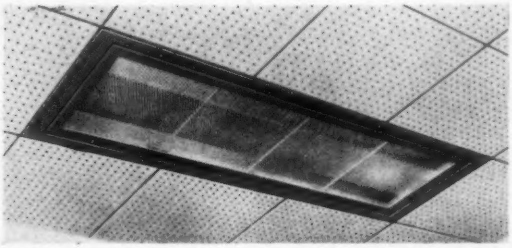


The AEI exhibit in the shop-window arcade.

Above, the Harris and Sheldon stand. Below, the Siemens Edison Swan stand.

Left, the GEC "Comfort" fitting for MBF lamps, and above, the twin fluorescent lamp "Comfort" fitting with extruded "Diakon" sides.


A group of Holophane fittings; top left, the HV 200; below left, the AMV 1; above, a fitting to be used in the new Shell building.

standard Warm White fluorescent lamp has a higher maintained "average through life" performance than that of other companies, the 80-watt 5ft. lamp giving 4,720 lumens; they rather naturally declined to say how they do it! The A.E.I. Lamp and Lighting Co. featured their "Netalamp," a flattened version of the standard 60-, 100- and 150-watt GLS silverlight. They look attractive and their size should influence the design of fittings for filament lamps so long as the danger of the wrong lamp being installed can be overcome.

There appeared to be a large import of German "Radium" lamps in the small low voltage reflector lamp series (12v. 50-watt ES holders), and also in the silica coated decorative candle lamp types for use in multi-armed brackets; it seems a pity that this should be thought necessary.

Lighting development

Comfort

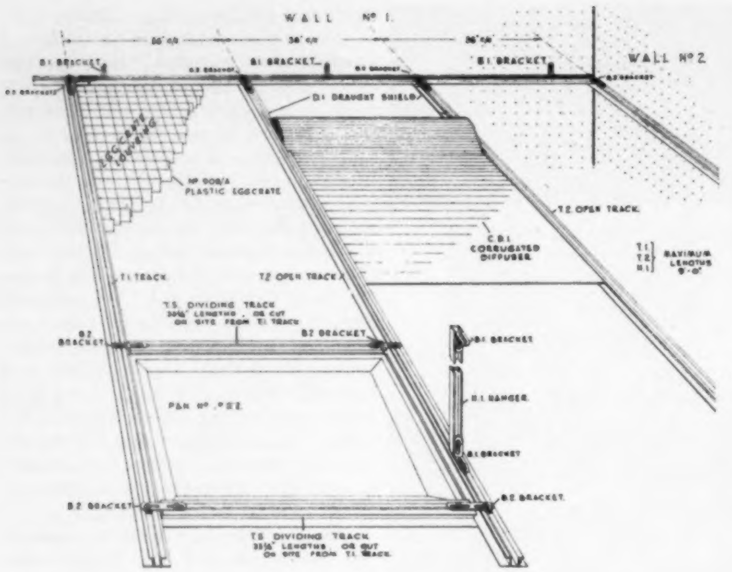
The most interesting trend in the exhibition was almost certainly a return to first principles in lighting design, the realisation that higher levels of illumination merit special types of lighting fittings. This was most clearly seen on the GEC stand where their new range of fittings to provide "comfort lighting" was demonstrated. There is nothing new in the principle used and there are a number of standard fittings of similar design available in America; they were used for lighting Case Institute in Cleveland some years ago. Similar fittings are also available in Scandinavia and were illustrated by Paivarinne in his paper to the IES at Eastbourne last year. None the less the GEC should be congratulated that they are the first to recognise the need here and to provide for it with a number of extremely well designed fittings for both commercial and industrial use. The fittings use the principle of direct light sources with specular aluminium reflectors for maximum efficiency, the reflector design and louvres cutting off the brightness of the lamp from normal angles of view; at the same time the reflector appears dark except when seen from directly below, so that high levels of illumination (100 lm/ft^2) may be obtained without glare, the brightness of the fitting corresponding to the brightness of the ceiling. This will be of the greatest assistance in obtaining comfortable "recessed" lighting, but it will also be of use to achieve comfortable and efficient lighting from surface-mounted or suspended fittings.

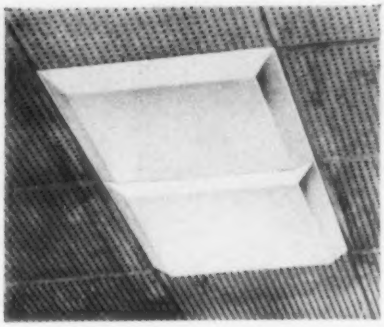
Holophane, themselves generally leaders in the "comfort" field, demonstrated two new fittings for use with tungsten filament lamps, the HV 200, a surface-mounted fitting for use with 200-watt or two 150-watt GLS lamps, and the "Lentillite 462" for use with 100- to 300-watt GLS lamps; both use prismatic methods to control brightness. Holophane also exhibited two new wall fittings, the AMV 1 being of good appearance; other fittings illustrated the control of glare from recessed fluorescent fittings by prismatic means, the fitting for use in the new Shell building being exhibited.

The promise of co-operation between the Rambusch Co. of America and Troughton and Young made at last year's exhibition was fulfilled in some measure by a single recessed "downlite" fitting for use with a 1,000-watt GLS lamp. Fittings of this design have already been installed in a large store in London with success, and the development of fittings for use with lower wattage lamps should follow. The design is based on the use of a super-purity aluminium reflector with a carefully controlled crossed beam, enabling a high proportion of useful light to be thrown through small "black" apertures in a ceiling at considerable heights. This should be of the greatest use to architects who always appear to want light "down here" with nothing "up there."

Luminous ceilings and integrated lighting

The luminous ceiling continues to thrive and has now reached the "do-it-yourself" stage. Following Ted Wakefield's example in America, Courtney Pope have marketed their "Brite-Glo" ceiling at a price of £18 18s. 0d. The illustration shows the ceiling installed in the "Berg" house at the neighbouring Ideal Home Exhibition. The ceiling, 6 ft. by 4 ft., is formed of standard 2 ft. square vacuum formed vinyl panels set in a special "clip-together" metal framework supported on chains below two fluorescent batten fittings. The whole outfit, together with lamps and control gear, comes in a packaged kit to be put up by an average "handy" man or local electrical contractor. At this price Courtney Pope must be hoping to sell a large quantity of ceilings for the





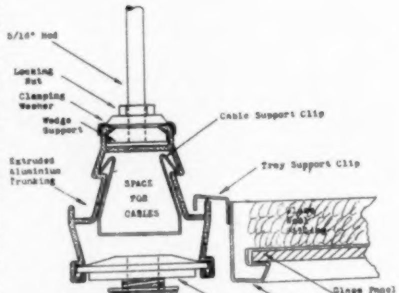
Above, Layout of the Lumitron ceiling. Right from top to bottom, panel of the Siemens-Celotex ceiling; the Courtney Pope "Brite-Glo" ceiling in a kitchen; section of the Atlas integral trunking; the Courtney Pope "Flexigrid" ceiling.

project to be successful, and one of their difficulties will certainly be the very dreary standard of home design in this country. Courtney Pope tend to do things a little ahead of public opinion and it is to be hoped that this will not prove another instance, for such a ceiling would be an undoubted improvement to so many kitchens and bathrooms throughout the country.

A further example of the "do-it-yourself" approach came from Lumitron, though aimed more at the electrical contractor than at the householder. Their "Multi-purpose suspended ceiling" is designed to accept vinyl pans, corrugated vinyl sheet or louvres, with opaque panels with recessed tungsten filament units where required. The suspension arrangements are simple and inexpensive, but the "track" supporting the diffusers is $2\frac{1}{4}$ in. wide with a fluted undersurface, which appears very heavy due to the central wiring conduit for use with surface mounted tungsten spots for display purposes.

The GEC "Lumenated Ceiling" employed the new pyramid diffuser with their Lumenator Module grid to good effect. Crompton Parkinson demonstrated the use of colour filters as an alternative to coloured panels where colour is required in a luminous ceiling; though this has the advantage of increased light transmission, with easier interchangeability, the colours themselves need further thought.

The Siemens Ediswan-Celotex ceiling is an excellent example of co-operation between a ceiling manufacturer and a lighting equipment manufacturer. Here the standard ceiling suspension is employed to support simple trays carrying lamps and gear above, with moulded "Perspex" diffusers below. The standard size of unit is 2 ft. by 1 ft. with a centre indentation to give the same appearance as the ceiling itself, that of a 1 ft. square panel. Units can be placed anywhere in the ceiling, provided the area is planned to be free of obstructions, and will be as interchangeable as the electrical distribution will permit. In appearance the system overcomes the "frame" appearance of the standard "module" fitting, and as units can be placed side by side or end to end, patterns or large luminous areas can be provided. The extraordinary thing is that so little such co-operation exists in service ceilings, where lighting, acoustics, and other controls can be integrated.



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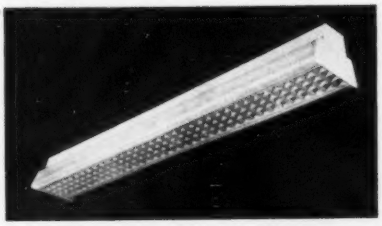

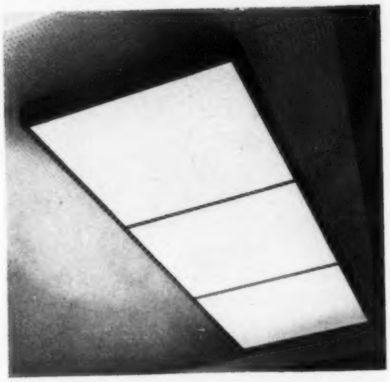

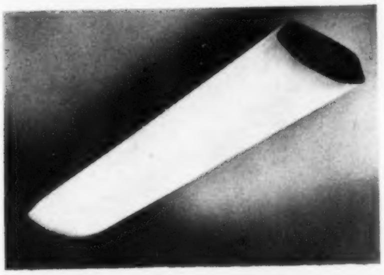

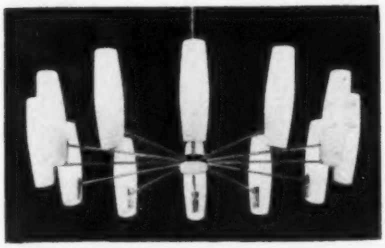

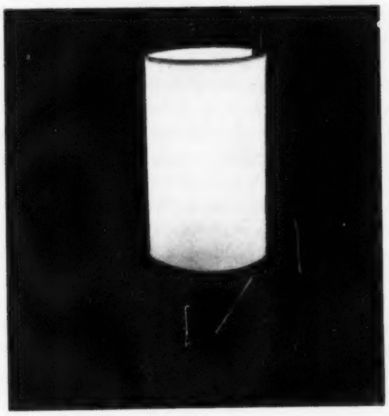

Left from top to bottom, example from the Falk's "Summit" range; Harris and Sheldon shallow module fitting and black-ended fitting; example from the GEC "Vari-form" range; and the AEI "Fiesta" table lamp. Above, the Frederick Thomas teak-sided fitting.

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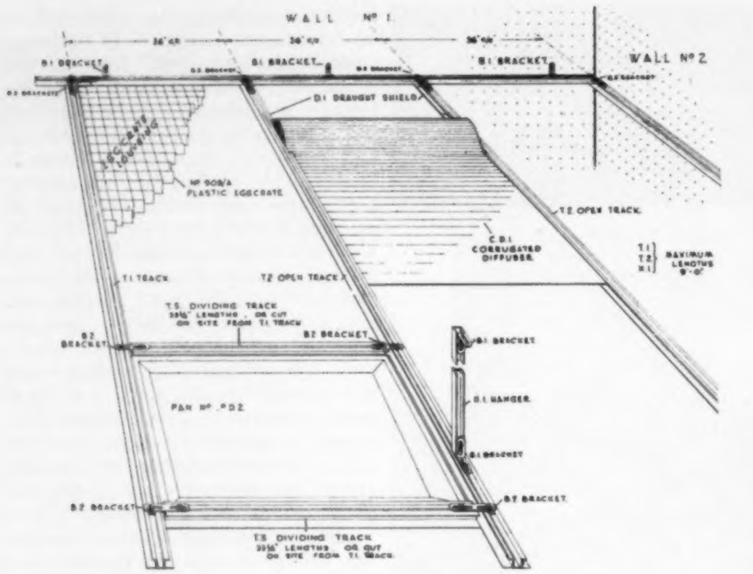

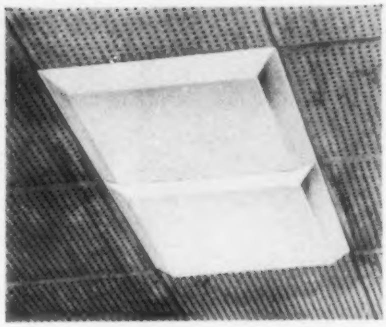

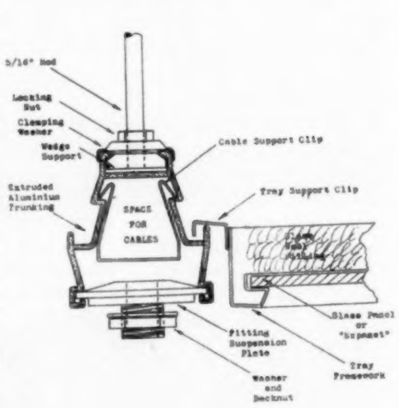

Above, Layout of the Lumitron ceiling. Right from top to bottom, panel of the Siemens-Celotex ceiling; the Courtney Pope " Brite-Glo " ceiling in a kitchen; section of the Atlas integral trunking; the Courtney Pope " Flexigrid " ceiling.

project to be successful, and one of their difficulties will certainly be the very dreary standard of home design in this country. Courtney Pope tend to do things a little ahead of public opinion and it is to be hoped that this will not prove another instance, for such a ceiling would be an undoubted improvement to so many kitchens and bathrooms throughout the country.

A further example of the "do-it-yourself" approach came from Lumitron, though aimed more at the electrical contractor than at the householder. Their " Multi-purpose suspended ceiling " is designed to accept vinyl pans, corrugated vinyl sheet or louvres, with opaque panels with recessed tungsten filament units where required. The suspension arrangements are simple and inexpensive, but the " track " supporting the diffusers is 2¼ in. wide with a fluted undersurface, which appears very heavy due to the central wiring conduit for use with surface mounted tungsten spots for display purposes.

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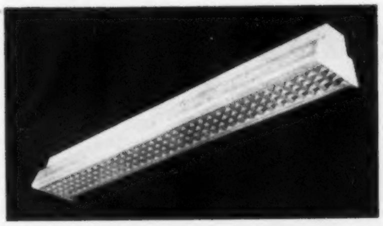

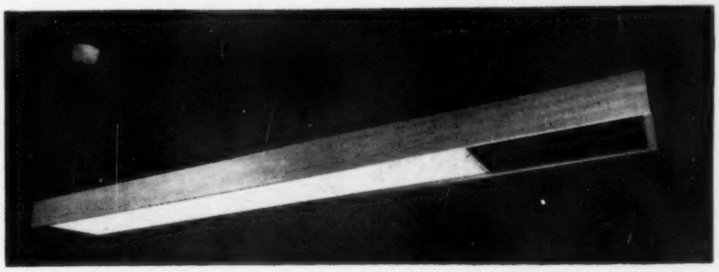

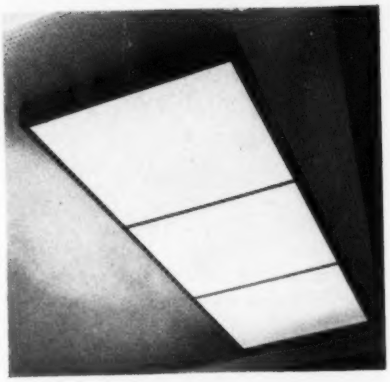

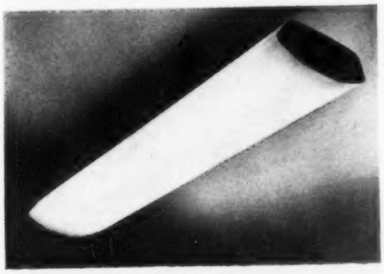

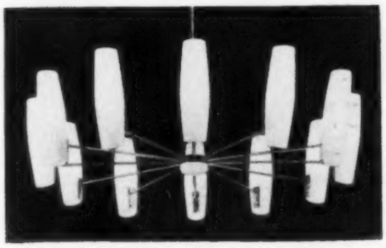

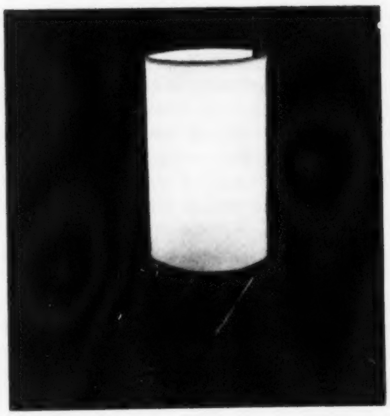

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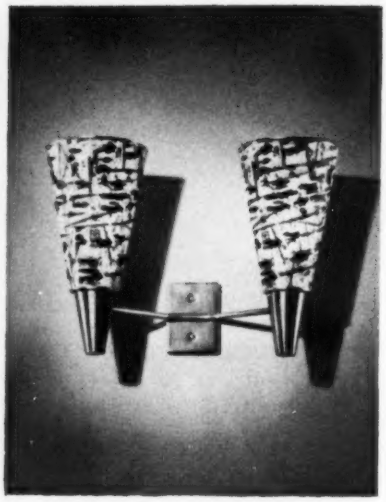
Top left, Hume Atkins gymnasium fitting; right, Courtney Pope "dynamic" spotlight.

Below left, H. W. Field's "Fildenex" shade; right, example from the GEC "Friendly" range.



dant or wall bosses, with various forms of glass and plastic shade. The parts are all interchangeable and include the wiring which is joined together when the fitting is assembled. The number of different combinations is almost inexhaustible, and is said to reach the million mark—which will give architects a great opportunity to exercise their own judgment and to select useful combinations for each specific job. The A.E.I. Lamp & Lighting Co. exhibited their "Fiesta" range of decorative fittings suitable for use in hotels and the more decorative parts of commercial buildings; a small table lamp appealed particularly. Troughton and Young featured a new opal glass shade in different sizes produced to T & Y design by an English glass manufacturer which indicates that with patience the English glass industry is capable of delivering the goods.

In the more utilitarian field Hume Atkins exhibited their range of tungsten fittings for schools and gymnasia, their HA 420 fitting for 300 to 500-watt GLS lamps being particularly useful.

Shop and display

The designer of shops or display stands is richly provided with well-designed fittings and numerous companies have entered this promising field. Courtney Pope have turned their hand to "dynamic" lighting in the form of a rotating spotlight, which was shown in use both on their display stand and in their shop in the arcade, though it was difficult to judge its effectiveness due to the generally high levels of lighting.

Home lighting

At 4s. 11d. the H. W. Field "Fildenex" shade was probably the best value for money to be found. The shade is blown from polyethylene in the same manner as cosmetic bottles, and is designed to withstand the normal heat from 100-watt lamps when held on a shade ring. The shade comes in opal which is pleasant, and some pastel shades which are not. At this price (of which 11d. is purchase tax) it would not be much of a financial burden to replace all the discoloured or broken shades around the home and to provide shades wherever bare lamps are used in out-of-the-way-places.

At £3 11s. 9d. the two-lamp wall bracket in the GEC "Friendly range" is a less reasonable proposition. Atlas are still pioneering the fluorescent domestic market, following their "kitchen light" with 4 ft. "Perspex" enclosed fittings using a combined starter/ballast lamp. It is difficult to see quite where these can be used, except in kitchens or bathrooms. Home lighting would make an excellent subject for next year's special feature at the exhibition and if it were to point out the weakness in lighting equipment for this purpose it would be performing a considerable service. If ten manufacturers were to be given different areas of the home to develop, perhaps in conjunction with interior designers, the results could be most rewarding.

Some Differences in Lighting Codes

By H. C. WESTON

This article discusses the differences between the ranges of recommended values of illumination in the American, British and Russian lighting codes, and gives some explanation of these differences.

Attempts to formulate standards of lighting have been made from time to time during the past 170 years. In the last decade of the 18th century, Count Rumford, "the first illuminating engineer"[1], concerned himself with this matter in connection with workshops, and so began his contributions to photometry and the "art of illumination." However, nearly a century elapsed before any extensive photometric survey of prevailing conditions of lighting in buildings was made and followed up by the recommendation of a definite minimum level of illumination. The credit for this pioneer work belongs to Hermann Cohn, who was Professor of Ophthalmic Science in the University of Breslau. In 1883 his academic colleague, Dr. Leonhard Weber, devised a convenient portable photometer which Cohn was able to use in his investigation of lighting in German schools. Weber also introduced the "meter-candle" (since termed "lux") as a standard of measurement. Cohn made his proposal for the minimum illumination in classrooms in terms of this unit. Some thirty years earlier another Weber—Ernst Heinrich Weber—had published the results of experiments showing the constancy of the ratio which two stimuli, e.g., of luminance, bear to each other when they are just perceptibly different. The constancy of this relative difference (which holds only over a certain range of stimulus intensities) was termed "Weber's Law" by Fechner, who was one of Weber's pupils. Weber's Law and the "Fechner Fraction" have given rise to immense discussion which will not be augmented here, though they are not irrelevant to the subject of this article.

Cohn posed the question "how many meter-candles are desirable for reading and writing?", and he based his answer upon actual trials. "I find," he wrote, "that a newspaper, printed in the so-called *bourgeois* type, can be read at a distance of one metre just as easily and quickly when illuminated by light equal to 50 meter-candles (4.65 lm/ft^2) as when read by good daylight." Then—proceeding to his recommendation—". . . we are asking nothing unreasonable when we fix as the minimum of hygienic requirements the fifth part of the amount of light by which we can read as quickly and as far off as by day. We ought, therefore, not to approve the use of a flame and lampglobe at so great a distance that the paper's brightness is less than 10 meter-candles" (i.e., 0.93 lm/ft^2).

We may dwell awhile on this question of the illumination desirable for reading, because reading is one of the most widespread of all visual tasks, and quite a number of different illuminations have been prescribed for it in the last 75 years—most of them in the latter half of this period. The type size on which Cohn based his conclusions was 8-point and to a viewing eye at a distance of 1 metre the critical detail of letters of this size subtends at angle of about one min. of arc. Such a visual size is very small, yet Cohn thought it could be read easily with 5 lm/ft^2 (more precisely, with 5 dekalux*) and that the hygiene of the eye might be safeguarded provided the illumination was not less than 1 lm/ft^2. Ability to discriminate detail of this visual size is the conventional index of "normal vision" and it may be mentioned that so late as 1919 the Council of British Ophthalmologists recommended that the illumination of test-letter charts should not be less than 3 lm/ft^2. However, when 8-point type is viewed not at a distance of 1 metre, but at the more usual reading distance of about 13 inches, the apparent size of its detail is nearly 3 mins. instead of only 1 min. So, if Cohn's value of 5 lm/ft^2 was virtually as good as daylight for reading 8-point at 1 metre it might be expected to be ample for reading this type at the ordinary reading distance. Now, in 1917 Luckiesh[2] gave 3-6 f.cs. as the then acceptable illumination in libraries. Trotter[3], in 1921, gave 3-4 f.cs. for library tables. Walsh[4], in 1923, wrote "for reading and writing it is now generally agreed that an illumination of about 3 foot-candles is the most comfortable." In 1924, the so-called Geneva Code of the CIE[5] recommended 5 f.cs. as the minimum for school library tables. In 1931 our own IES recommended a minimum illumination for reading of 5 f.cs.[6]. By 1935, some of the basic data obtained by the present writer had been published[7], and from these data it appeared that a visual task presenting the detail and contrast of 8-point type can be done with a visual efficiency of about 90 per cent when the illumination is about 6 lm/ft^2, the performance rising to 95 per cent of the maximum if the illumination is doubled. Further data published in 1943[8] confirmed these values. Acting on these findings, the Lighting of Buildings Committee of the BRS (DSIR) recommended in their 1944 Report[9] that there should be not less than 12 lm/ft^2 on school library tables. In the following year the new IES Code was published and gave 15 lm/ft^2 as the standard for reading tables. Three years earlier, however, Luckiesh and Moss[10] claimed that "the optimum level of illumination for reading a well-printed book of 10-point type [i.e., larger than 8-point] is above 100 f.cs." and even that "250 f.cs. for reading appears to be below the optimum for easiest reading." In the 1947 edition of the Lighting Handbook of the American IES, 30 f.cs. is recommended for libraries, 40 f.cs. for prolonged reading in homes and 20 f.cs. for casual reading. Similar values are currently recommended. In 1958, new norms for electric lighting in buildings were issued in Russia[11]: 30 lm/ft^2 plus local lighting is prescribed for library reading rooms, although the value is 10 lm/ft^2 "in central libraries" and only 7.5 lm/ft^2 "in other libraries." Classroom desks in schools are also to have 30 lm/ft^2. Shaikevich[12], in 1958, published the results of his experimental studies of visual performance which appear to support the Russian values. Finally, and also in 1958, Blackwell presented to the Ameri-

* 1 dekalux = 10 lux = 10 meter-candles. The term 'dekalux' is introduced here because the quantity it names is so nearly equal to the lumen per sq. ft. or foot-candle that, in this context, the same number may be used in quoting recommendations whether the units be taken as English or metric.

can IES his new basic data and proposals for specifying necessary values of illumination[13]. Blackwell's method entails the instrumental evaluation of visual tasks so as to enable the required brightness to be found from "a specification curve." He finds the illumination necessary to give 8-point type a "suprathreshold visibility" of 15, and to afford a visual capacity of "5 assimilations per second" with the "maximum practical accuracy" is, according to the fount, 1.13 or 1.87 lm/ft^2, and only 0.94 lm/ft^2 if the type is 10-point—for which, as stated above, Luckiesh and Moss consider the optimum is some 250 times greater.

Now, if the reader has managed to endure the tedium of the foregoing recital, he will have been made aware of the seemingly remarkable fact that during the three-quarters of a century in which numerical standards of illumination have been formulated, the standard proposed for reading has gone all the way from a minimum of 1 lm/ft^2 to upwards of 250 lm/ft^2 and back again to 1.

It is common experience that reading can be done at any illumination within this range and also at illuminations beyond it. Most other visual tasks can also be done at different levels of illuminations, without any demonstrable difference of comfort or efficiency provided the lowest illumination of the range is good enough for the job. In other words, "enough is as good as a feast." The question at issue is what is enough? And this is the question that propounders of lighting codes seek to answer.

That the answers given in the case of seeing what has to be seen in reading have differed so much is not, in fact, quite so surprising as the numerical values suggest. The differences between these values are arithmetic differences but, differences in visual capacity are more nearly proportional to the logarithms of the numbers than to the numbers themselves. Between Cohn's hygienic minimum of 10 lux and the 50 lux he judged to be "as good as daylight" for reading (by no means an easy judgment to make) there is a ratio of 5, or a difference of 0.7 log unit. The British IES has advanced this estimate of what is "enough" by a little less than half a log unit, and the American and Russian Codes have doubled it. There is experimental evidence in support of these advances upon Cohn's estimate, but they have brought us into the region of rapidly diminishing returns where further increments—even if relatively large—become increasingly difficult to justify by any criteria we can measure. The great surprise is that the most recent "valid, scientific basis of foot-candle recommendation" from which "we know how to evaluate with reasonable accuracy what quantity of light should be our goal in providing illumination for any given seeing task"[14] has produced a "footcandle recommendation" of less than 2 for the task we have been considering.

Does this cast doubt upon the validity of the basis upon which it rests? Not necessarily. For, if the basis can be shown to lead to the chosen objective—in this case a visual performance of 5 assimilations per second with 99 per cent accuracy—then to this extent it is valid. But is it suitable? That is the most important question. The method referred to yields higher values for visual tasks in the upper reaches of the difficulty scale and lower values for some of the easier visual tasks than do other methods. Accordingly, the values range from less than 1 to more than 10,000 lm/ft^2—that is to say, a range at least twice as wide as that which could be supported by the present writer's "basic data" published in 1943[8] and republished more completely in 1953[15]. The range actually adopted in the present British IES Code for a similar range of task variables is 1:1,000 and the corresponding range in the Russian "Norms and Rules" is only 1:30.

The very wide range of values given by the Blackwell method, including, as it does, impracticably high and untried values, is a necessary consequence of choosing as a performance criterion a single rate of assimilation, *viz.*, 5 APS. This is so because if this rate is attainable with very difficult visual tasks at a level of illumination involving—figuratively speaking—"reaching for the sun," it is much below the rate attainable with the easy tasks for which the system caters, except at a level of illumination which involves "reaching for the twilight."

It was just because investigation showed the concept of equal visual performance of very differently constituted visual tasks to be a false ideal, requiring for its realisation very high illuminations on the one hand and quite unacceptably and uneconomically low values on the other hand, that the present writer put forward in 1935[7] the alternative and quite practicable criterion "equal *relative* visual performance." This means that although—as experiment and common experience have shown—the differently difficult visual tasks a, b, c, . . . differ in the maximum rate at which they can be performed even under the most favourable illuminations, an illumination specification system can be both self-consistent and realistic if it leads to recommended levels which suffice either for the respective maximum performances of tasks a, b, c, . . . to be attainable (however different such performances may be) or for some constant proportion or percentage of these different maxima to be realisable.

Obviously, other criteria are possible, such as a graded series of rates or of relative rates of performance. Such a system as this has the effect of contracting the range of recommended illuminations and, if carried far enough, will give a very narrow range of values. Herein lies the explanation of the discrepancies between the new American, the British and the Russian code ranges which have been pointed out already.

Instead of aiming at one standard rate of "assimilation" or "differentiation," as in the latest American system, the Russian norms are based on a "sliding scale" of performance rates; the rate for the most difficult tasks is low—as it must be—while the rate for the easiest tasks is high—as it can be. This is quite rational and results in recommended illuminations which range from 10 lm/ft^2 to 300 lm/ft^2. It is not denied that values higher than the maximum of this range can be useful, in that they make it possible to cope with tasks presenting slightly lower contrasts without losing speed of performance. But it is argued that, in practice, any advantage from higher values (up to 1,000 lm/ft^2 has been tried) tends to be neutralised by "side effects."

The criterion adopted in the British Code really amounts to a compromise between the author's "equal relative visual performance" and the Russian "sliding scale" of performance rates. The British recommended values of illumination are not based on a single standard of relative performance (often quoted as 90 per cent), but on a relative performance of *not less than* about 90 per cent. Values for the most difficult tasks are those estimated to allow this criterion to be at least just realised; those for the easier tasks allow of performances between 90 per cent and the maximum possible. The system is essentially one which recognises that different absolute rates of performance of widely different visual tasks must be accepted as "realistic" and that by no reasonable scaling up and down of illumination can these differences of performance be entirely "ironed out." Of course it is not a rigid system, but one

which can be modified if desirable without departing from the principle underlying it and wherein it differs crucially from the new American system.

As to the British standard of relative visual performance, it has been objected that this is too low and that pre-Blackwellian American recommendations corresponded approximately to a standard of 98 per cent. Now that the American IES recommended values have been raised by an average factor of about 3 they should be adequate for a standard of relative performance somewhat better than 98 per cent. Curiously enough, however, the 5 APS they are intended to allow is only half the rate that is suggested as being possibly the maximum attainable. However, the author of the new American system has said, "it is very difficult to know how many assimilations per second to give the eye credit for" and "if you have large amounts of information present" [as happens in many practical visual tasks] "it becomes extremely difficult to decide what the eye is doing and you are therefore unable to determine what the rate of assimilation is"[16]. In view of this, and of what has been said already concerning an absolute standard of visual performance, it does not seem unreasonable to wonder whether the choice of such a criterion has been a wise one.

One phrase in the foregoing quotation brings us to the final point in this very incomplete critique of lighting codes; it is "to decide what the eye is doing." The essence of Beuttell's original suggestions for a lighting code[17] was that the task should be "taken to pieces" so as to disclose its critical detail and so enable a suitable illumination value to be found by reference to predetermined basic data of the necessary kind. To apply the recommendations of a "scientific" lighting code to practical visual tasks without assessing their relevant characteristics with reasonable care and skill does not lead to "scientific" lighting. Such practice is as inexact as would be that of the doctor who wrote prescriptions without first doing his best to diagnose the patient's illness. The present writer has on various occasions stressed the need for better task analysis, so that too much of such precision as it is possible to claim for the fundaments of lighting codes which are not entirely empirical shall not be unreflected in the "end product." In so far as published classifications of practical "tasks" are valid—and it must be admitted that such classifications are, at present, largely based on the current "consensus of informed opinion"—they relieve lighting engineers of the sometimes difficult business of task analysis. But there are numerous tasks which are not scheduled and which, therefore, must be assessed when they are met with. One of the merits of the British IES Code is that it gives the lighting engineer useful guidance on how to make a reasonably good assessment, even if he is unable actually to measure the task. It tells him and shows him, e.g., what is meant by the terms "small," "very small," etc. Now it would be very nice if this troublesome business of task assessment could be done by means of an instrument and, of course, this has been attempted by various people in several countries. Dunbar[18] has discussed the principles and results of such "visibility" meters and no comments on them will be made here. However, both the new American recommendations and the Russian norms stem from visibility meter evaluations of sample tasks. Blackwell's "visual task evaluator" appears, at present, to be a piece of laboratory apparatus which cannot yet be used in ordinary practice. With this meter he has evaluated over 50 "types" of task which are briefly described so that actual field tasks which are not specifically listed in the foot-candle schedules can be compared with one or other of the evaluated types and the appropriate illumination adopted. Unfortunately, the descriptions of evaluated tasks are too imprecise to enable other tasks to be matched with them confidently for the purpose of finding the required illumination. For instance, the descriptions contain such undefined terms as "broken thread," "small spot," etc. Like the British Code, that of the Soviets defines size in terms of object dimensions and viewing distance, and contrast in terms of reflection factors. Perhaps more can be done to help lighting engineers to apply code recommendations correctly, but more should also be done by lighting engineers to cultivate skill in task analysis and assessment. Meanwhile, if "the policeman's lot is not a happy one" nor, let it be understood, is that of the lighting code maker!

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Discussion on Lighting Codes

A meeting of The Illuminating Engineering Society at which the levels of illumination recommended in different countries will be discussed is to be held at 6 p.m. on Wednesday, July 8th, at the Federation of British Industries. Those taking part include Dr. Blackwell and Mr. Crouch, of the U.S.A., and Dr. Dresler, of Australia. It is hoped that a representative of the USSR will also be present. The reasons for the differences now existing in the codes of various countries will no doubt be explained and the meeting on July 8th ought to be a very instructive one.

A translation of the Russian recommendations is now available in the form of two documents (*i*) the Russian industrial lighting code consisting of building norms and rules, by the USSR Ministry of Building, and (*ii*) Classification of visual tasks, by A. S. Shakevich, of the Leningrad Industrial Health Institute. The two documents, which include all diagrams, etc., can be obtained from the Permagon Institute, 4, Fitzroy Square, London, W.1, price £7, or from their New York office, price 20 dollars.

Polar Curves of Sector Flux and Illumination from Linear Sources

By H. E. BELLCHAMBERS, A.M.I.E.E.*

IN the May, 1957, issue of *Light and Lighting*, Dr. Walsh in his inimitable manner led us gently through the intricacies of sector-flux and illumination calculations from long linear light sources, without the aid of the differential calculus. However, some of the more discerning readers may have wondered how, in practice, the polar curve of sector-flux for a long linear light source can be determined.

As Dr. Walsh has pointed out, sector-flux is the product of illumination and radial distance from the source to the illuminated point. But how does one determine this, since it would seem to involve measurement of illumination from an infinitely long source ?

A further question that may be asked is, how does one determine the illumination from a finite length of a long linear light source ?—a condition often met in practice.

The sector-flux method is an extremely useful tool for the lighting engineer who is engaged in the design of installations using either symmetrically spaced rows or non-symmetrical spacings. But in order to use the method fully, means of determining the polar curve of sector-flux and the illumination from a finite length of practical sources are essential. These may be determined from the polar curves of intensity which are easily measured in most photometric laboratories.

Determination of Polar Curves

Einhorn and Ackerman† have described a method of measuring sector-flux in which two mirrors are placed facing one another, one at each end of a finite unit length of a long linear light source, so that multiple reflections introduce, in effect, an infinitely long source. Then at some fixed distance from the source a photo-cell is rotated around the axis and illumination is measured at frequent angular intervals (Fig. 1). A correction factor is applied to compensate for multiple losses in the mirrors and then the illumination in each angular direction for which it has been measured, is multiplied by the distance R to obtain the sector flux J, and the polar curve can then be constructed.

The value of sector flux is determined by the nature of the intensity distribution (ψ function) in the vertical plane containing the source axis and Einhorn calculated the factor J/I_0 where I_0 is the intensity in the direction of $\psi=0$ (see Fig. 2) for three easily defined axial intensity distributions.

These were constant intensity, diffuse (cosine) and cosine² distributions. The values of these factors J/I_0 for the three distributions are given in Table 1.

Table 1

J/I_0 Factors

Distribution	Constant Intensity	Diffuse	Cosine²
J/I factor	2	1.57	1.33

Thus if the intensity per unit length is I_0 in any direction in the plane normal to the source axis, and the axial intensity corresponds to one of the distributions in Table 1, then the value of J is obtained by multiplying I_0 by J/I_0.

Fig. 1. Illumination from long linear sources.

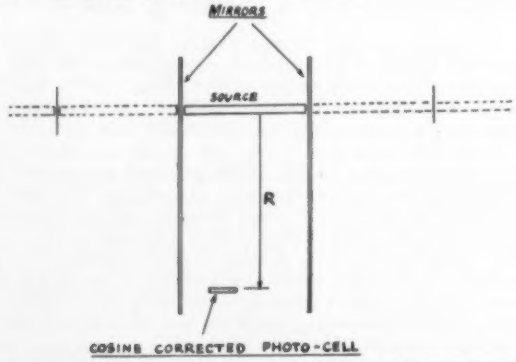
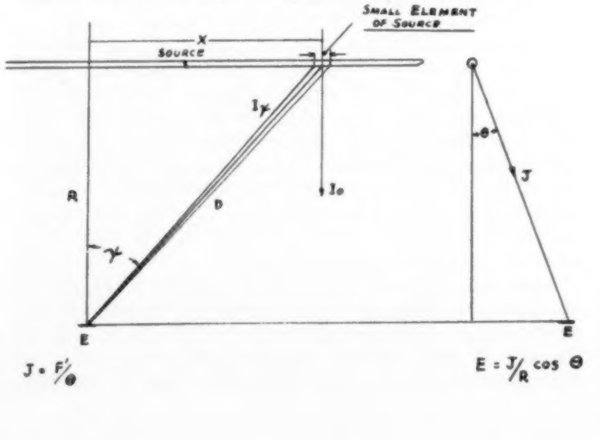


Fig. 2. Measurement of section flux using two mirrors.



* Application Development Department, A.E.I. Lamp and Lighting Co. Ltd., Leicester.

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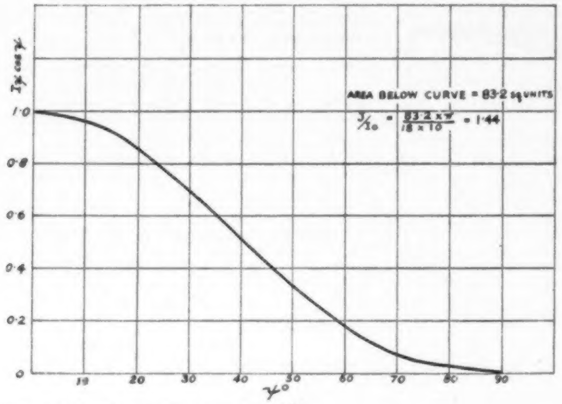
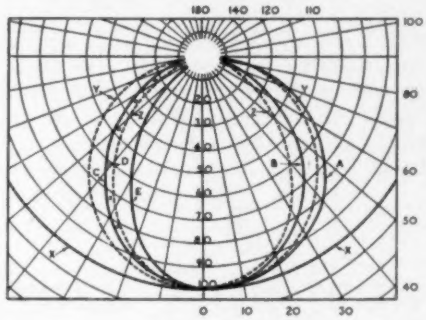


Fig. 3 (above). Determination of J/I_0

Fig. 4 (right). Axial intensity distributions and J/I_0 *factors.*

KEY LETTER	SOURCE TYPE	J/I_0 FACTOR
X	CONSTANT INTENSITY.	2·00
Y	COSINE DISTRIBUTION.	1·57
Z	COSINE^2 DISTRIBUTION.	1·33
A	MATT REFLECTOR.	1·61
B	SPECULAR REFLECTOR.	1·47
C	FLUSH MOUNTED 040 PERSPEX.	1·44
D	LOUVRED WITH PERSPEX SIDES.	1·38
E	FLUSH MOUNTED DEEP LOUVRES.	1·12



There are, however, a number of possible axial intensity distributions in a practical range which are intermediate between those given in Table 1. The following method can be used to determine the J/I_0 factors for any practical luminaire distribution from values of intensity measured in the normal manner on a polar co-ordinate photometer, using a finite unit length of a long linear light source.

By definition $J=F/\theta$, where F is the flux emitted per unit length within a sector of angle θ when the angle θ becomes vanishingly small. Also J is the sum of the fluxes emitted by each small element of the unit length, and the flux from each small element is proportional to $I\ \psi \cos\ \psi$ where $I\ \psi$ is the intensity in the direction ψ. If, therefore, we plot the curve of $I\ \psi \cos\ \psi$ against ψ from $+\frac{\pi}{2}$ to $-\frac{\pi}{2}$ ($+90^\circ$ to -90°) the area below the curve will be proportional to the sum of the flux from each small element of the unit length of the long linear light source. That is, J which is equal to $\pi\times$ mean height of the curve.

From this we can simply obtain the factor J/I_0 since I_0 is the value of $I\ \psi$ when $\psi=0$.

In the practical case the intensity due to a unit length of the source is measured at say 10° intervals in the axial plane. These values are multiplied by the cosines of the corresponding angles thus obtaining values of $I\ \psi \cos\ \psi$ which are then plotted to any convenient scale, as ordinates against ψ as a base from 0° to 90°. Then by planimetry or any other suitable method the area below the curve is determined. This value multiplied by π/n, where n is the number of units to scale representing 0° to 90° ($\frac{\pi}{2}$), and divided by the intensity at 0° gives the J/I_0 factor for that particular source (see Fig. 3).

The J/I_0 factors for a number of luminaires have been determined in this way and the results, together with their corresponding polar curves of axial intensity distribution, are given in Fig. 4.

Illumination from Linear Sources

The sector flux method is intended chiefly for the determination of illumination from infinite and semi-infinite* sources but the illumination from finite sources can be determined quite accurately. Measurement has established that fluorescent lamp luminaires containing one or two lamps, in which, for a 5 ft. fluorescent lamp, the width of the luminaire does not exceed 15 in., can be considered as linear sources when the distance from the illuminated plane is not less than 4 feet.

At any point on a plane below an infinite source the illumination $E=\frac{J}{R}$ and at a point below the end of a semi-infinite source $E=\frac{J}{2R}$. The values at intermediate points varying between these limits at a rate depending upon the axial intensity distribution (ψ function) of the source.

Since the illumination $E=\frac{J}{R}$ it follows that the area below the curve $I\ \psi \cos\ \psi$ (Fig. 3), described above for the determination of J, is also proportional to the illumination at a point distance R from the source. Therefore, the illumination at a series of points below and at varying distances from one end of a semi-infinite source (i.e. a source extending to infinity in one direction only) can be determined by measuring the area between $\psi=0^\circ$ and a series of values of ψ up to 90°. These results can then be plotted as a fraction of $\frac{ER}{J}$ to a base of X/R where X is the distance from the end of the source to the illuminated point, measured parallel to the source (see insert Fig. 5). From these curves the illumination at any point below a semi-infinite or finite source can be determined.

A number of curves for practical sources have been determined in this way and the results are given in Fig. 5. Thus for a semi-infinite source $E=\frac{J}{R}\cos\ \theta\ (1-\triangle_a)$ and for a finite source $E=\frac{J}{R}\cos\ \theta\ (1-\triangle_a-\triangle_b)$ where $\triangle$ is the fraction of the illumination lost owing to the ends of the source being at a finite distance from the point illuminated.

* Semi-infinite source: a linear source extending to infinity in one direction only.

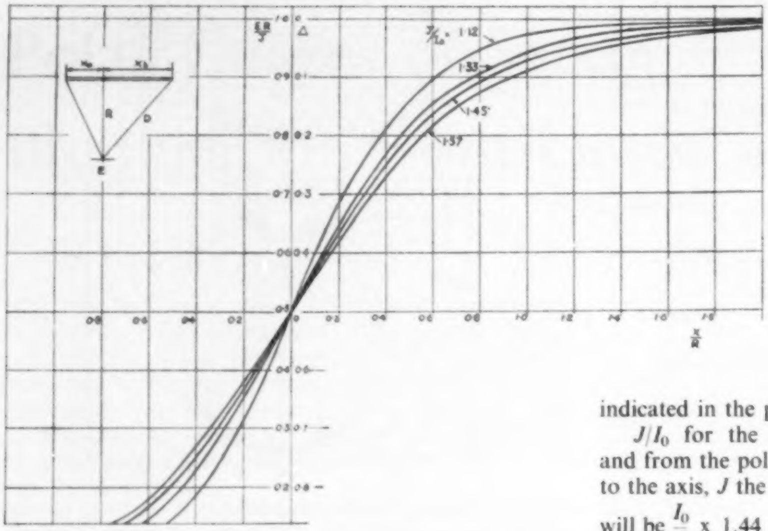


Fig. 5. Fall-off in illumination at end of semi-infinite source.

For vertical surfaces which are normal to the plane containing the source axis the curve $I\ \psi \sin\ \psi$ must be plotted and then the procedure is the same as for horizontal surfaces below the source. In the case of vertical surfaces it is more convenient to plot the illumination values obtained to a base of $\frac{R}{X}$. Examples of such curves are given in Fig. 6.

Examples of Method

The preparation of illumination diagrams, for a single length of fluorescent lamp luminaire such as those used for interior lighting design, can be accomplished by means of the illumination curves (Figs. 5 and 6) as described below.

The luminaire for which the calculations are made is a general diffusing one containing two 5 ft. 80-watt lamps and it has a width of 8 in. The results are compared with measured values.

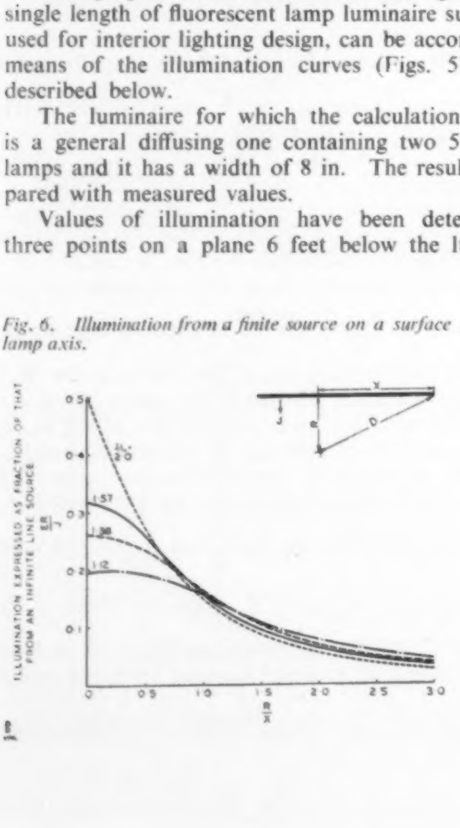
Values of illumination have been determined for three points on a plane 6 feet below the luminaire as indicated in the plan view Fig. 7.

J/I_0 for the luminaire under consideration is 1.44 and from the polar curve of intensity in the plane normal to the axis, J the sector flux per foot run of the luminaire will be $\frac{I_0}{5}$ x 1.44 where I_0 is the intensity in the direction of the line joining the luminaire to the point under consideration (Fig. 7).

R and θ can be obtained by construction.

Values of $\triangle$ are obtained from Fig. 5 for values of $\frac{X}{R}$.

Fig. 6. Illumination from a finite source on a surface normal to the lamp axis.



EXAMPLE 1

Illumination $E_1 = \frac{J}{R}\cos\theta\,(1-\triangle_a-\triangle_b)$.

$R=8.85$ $\theta=47.5^\circ$ $\cos\theta=0.676$.

$I=760$ cds.

$\frac{X_a}{R}=\frac{X_b}{R}=\frac{2.5}{8.85}=0.283$.

From Fig. 5 for $\frac{X}{R}=0.283$.

and $\frac{J}{I_0}=1.44$, $\triangle$ is 0.316.

$(1-\triangle_a-\triangle_b)=0.368$.

$E_1=\frac{760}{5}\times\frac{1.44}{8.85}\times0.368\times0.676=6.2$ lm/ft.^{2}

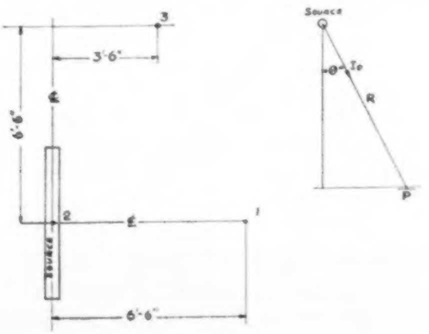
The measured value for the position was 6.4 lm/ft.^{2}

EXAMPLE 2

$R=6$ ft. $\theta=0$ $\cos\theta=1$.

$I\theta=880$ cds.

Fig. 7. Position of points used in illumination calculations.



$$\frac{X_a}{R}=\frac{X_b}{R}=\frac{2.5}{6}=0.416.$$

$\triangle_a$ from Fig. 5=0.245.

$$E_2=\frac{880}{5}\times\frac{1.44}{6}\times(1-2\times0.245)=21.5\ \text{lm/ft.}^2$$

The measured value for this position was 22 lm/ft.²

EXAMPLE 3

$R=6.92$ ft. $\theta=30°$ cos $\theta=0.866$.

$I\theta=830$ cds.

$$\frac{X_a}{R}=\frac{-4}{6.92}=-0.578.$$

$\triangle_a$ from Fig. 5=0.824.

Note values of X measured beyond the end of the luminaire are negative.

$$\frac{X_b}{R}=\frac{9}{6.92}=1.3.$$

$\triangle_b$ from Fig. 5=0.044.

$$E_3=\frac{830}{5}\times\frac{1.44}{6.92}\times.866\times(1-0.824-0.044).$$

$$=3.95\ \text{lm/ft.}^2$$

The measured value for this position was 3.9 lm/ft.²

In this way the illumination at points on horizontal surfaces below the luminaire, on vertical surfaces parallel to the luminaire axis, or on vertical surfaces normal to the luminaire axis can be calculated. If this is done for a series of points at regular intervals iso-lux or illumination diagrams can be prepared.

The Determination of Zonal Flux from Luminaires having an Asymmetrical Intensity Distribution

By H. E. BELLCHAMBERS, A.M.I.E.E.*

THE determination of the total flux from luminaires is generally obtained, in the case of axially symmetrical intensity distributions, from measurement of intensity at small angular intervals in two vertical planes at right angles to each other. From these measurements the flux in equal angular zones is determined by multiplying the mean intensity value for the zone by a zone factor, and the sum of the zonal fluxes gives the total luminaire flux.

Where the intensity distribution is asymmetrical, as it is with most fluorescent lamp luminaires, it is necessary to make measurements in more than two planes to obtain a reasonably accurate value. This frequently involves measurement of intensities in six vertical planes, values at each vertical angle being averaged for the six planes.

Development of Method

For linear sources, such as fluorescent lamp luminaires, the total flux per unit length can be given in terms of sector flux and sector flux can be determined from a knowledge of the intensity distributions in the two vertical planes containing the source axis and the normal to the axis.

By the sector flux method, luminaire flux per foot $F_u=2\pi J_{av}$. where J_{av}. is the average of all J values measured at equal angular intervals, J being the sector flux measured in lumens per foot per radian. It would, therefore, seem reasonable to determine total flux from fluorescent lamp luminaires using the sector flux method, thus eliminating the need for intensity measurements in more than two vertical planes.

However, there are occasions (for example when determining utilisation factors by either the Harrison and Anderson or the Jones and Neidhart methods) when it is necessary to determine the flux in each 10° zone for 0° to 90° and from 90° to 180°.

In the case of axially symmetrical distributions this is a simple matter but in the case of asymmetrical distributions average values in each zone are generally accepted even though this may lead to some small error in the computed value of the coefficient of utilisation. As mentioned before to obtain these average values involves measurement of intensity in at least six planes unless the sector flux method can be adapted to this purpose also.

For symmetrical distributions, flux is determined in conical solid angles and from sector flux data the flux within a solid angle forming a square pyramid can be determined (see Fig. 1). The size of the square pyramid solid angle bounded by say 10°×10° is not the same as that given by a 10° conical solid angle but the bounding angles of equivalent solid angles can be determined.

The flux within these two equivalent solid angles, for a given intensity distribution, will not be exactly the same owing to the difference in shape of the solid angles but the errors will be small. Table 1 gives the angles for the square pyramid solid angles which are equivalent to 10° conical solid angles.

Flux within the square solid angle determined from sector flux data will depend upon the axial intensity distribution (ψ function) as well as the distribution in the plane normal to the luminaire axis. Figs. 3-7 and Table 2 give multiplying factors for the determination of flux in equivalent 10° zones for axial distributions which

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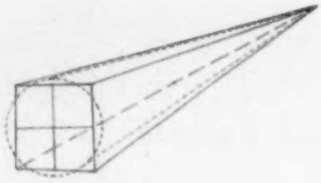

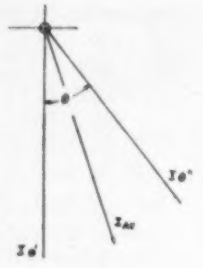

Fig. 1 (above). Equivalent square pyramid and conical solid angle.

Fig. 2 (right). Determination of zonal flux $F_z = I_{av} \times M$.

Table 1

Equivalent Solid Angles

Conical	Square Pyramid
0—10	0—9
10—20	9—17.5
20—30	17.5—27
30—40	27—36
40—50	36—45
50—60	45—55
60—70	55—65
70—80	65—76
80—90	76—90

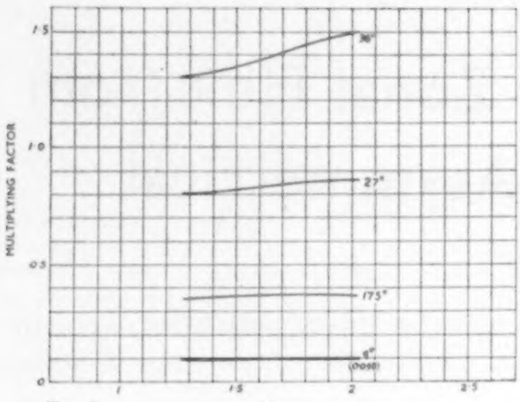

Fig. 3.

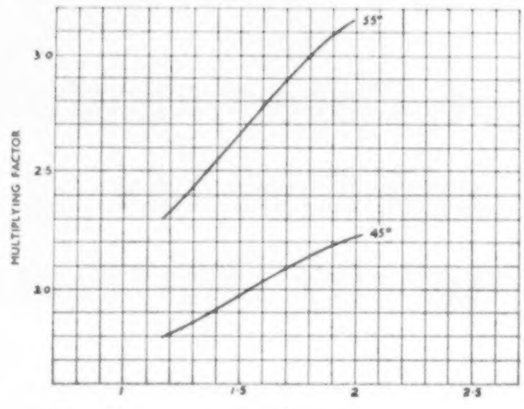

Fig. 4.

Figs. 3-7. Multiplying factors.

Fig. 5.

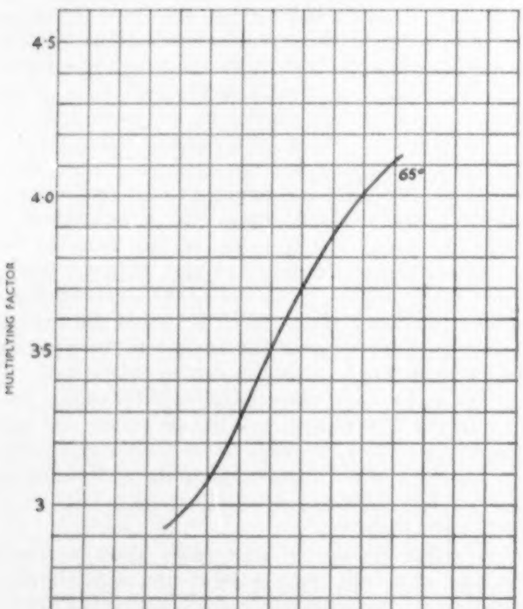

Fig. 6.

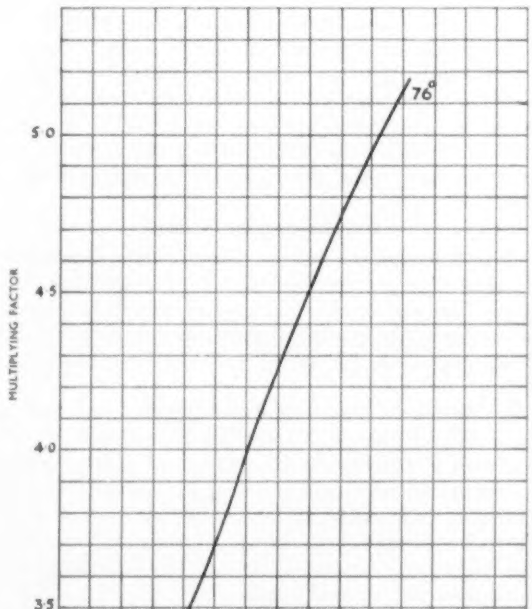

Table 2

Multiplying Factors, M

Zone Degrees	Constant Intensity	Cosine	Cosine^2
0—9	0.098	0.098	0.098
0—17.5	0.367	0.363	0.356
0—27	0.856	0.825	0.809
0—36	1.498	1.364	1.307
0—45	2.221	2.018	1.851
0—55	3.146	2.744	2.442
0—65	4.114	3.442	2.987
0—76	5.148	4.187	3.533
0—90	6.283	4.935	4.189

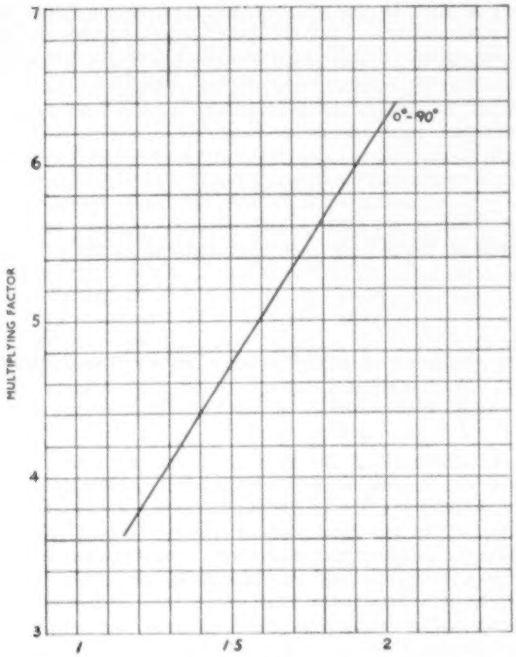

Fig. 7.

Table 3

Calculation of Zonal and Total Flux

Zone θ	Mean Value $I\theta$	Multiplying Factor M	Zone Lumens L
0—9°	552	0.098	54
0—17.5	545	0.36	196
0—27	534	0.82	438
0—36	522	1.34	700
0—45	510	1.97	1,005
0—55	496	2.66	1,318
0—65	479	3.25	1,555
0—76	459	3.98	1,826
0—90	437	4.69	2,048

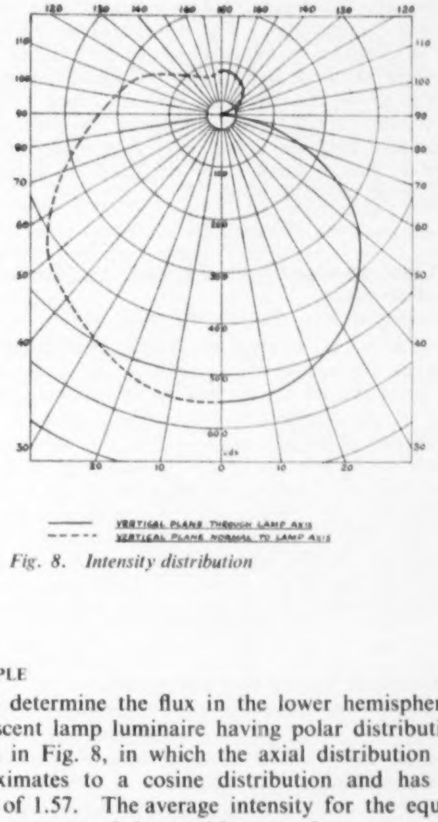

Fig. 8. Intensity distribution

cover the practical range of fluorescent lamp luminaires.

Application of Method

The method of determining the flux is to find the average intensity normal to the axis (Fig. 2) in the given zone and to multiply this value by the appropriate factor from Figs. 3-7 chosen according to the nature of the axial intensity distribution.

Multiplying factors are given in Figs. 3-7 in terms of the J/I_o relationship. The value of the J/I_o factor for any given axial intensity distribution can be obtained by the method described elsewhere.*

The multiplying factors M for the three distributions are obtained from the following formulae where θ is the zone angle measured from 0°.

Constant intensity

$$M=4\theta \sin \theta$$

Cosine

$$M=4\theta\,(1/2\ \theta-1/4 \sin 2\theta)$$

Cosine^2

$$M=4\theta\,(\sin \theta-1/3 \sin^3 \theta)$$

* Polar Curves of Sector Flux and Illumination from Linear Sources. See p. 162 this issue.

EXAMPLE

To determine the flux in the lower hemisphere of a fluorescent lamp luminaire having polar distributions as shown in Fig. 8, in which the axial distribution closely approximates to a cosine distribution and has a J/I_o factor of 1.57. The average intensity for the equivalent angular zones and the resulting zone lumens are given in Table 3.

The total flux determined in this way gives a value of 2,048 lumens and compares favourably with that of 2,000 lumens determined by the longer method based upon measurements in six vertical planes.

Limitations of Method

It should be noted that this method applies strictly only to axial intensity distributions which can be expressed as a function of a cosine, i.e. $I\,\psi=I_o \cos^n \psi$ but most fluorescent lamp luminaire distributions are of this form. Furthermore the values of zone flux obtained are equivalent to those derived by the more usual averaging method and do not fully describe the flux distribution.

Lighting Abstracts

OPTICS AND PHOTOMETRY

535.24

663. Automatic photometer for street lighting and other luminaires.

G. A. HORTON, R. C. SPECK, P. A. ZAPHYR and R. E. WENDT, *Illum. Engng*, **53**, 591-595 (*Nov.*, 1958).

Complete automation of a distribution photometer for street lighting and other luminaires has been achieved by using two motorised tape readers to control the luminaire and mirror orientations. The instantaneous luminous intensity is measured in terms of the current output from a barrier-layer photocell feeding into a self-balancing recorder. Connected to the recorder slide wire are a tape punch and an electrically-operated adding machine. The tape punch is used for recording the photometric data while the adding machine enables a check to be made on the accuracy of calibration of the instrument. P. P.

535.2

664. Visual photometer for the study of "Earth Shine" of the moon.

JEAN ROSCH, *Rev. Opt*, **37**, 458 (*Sept.* 1958). *In French.*

Description of a precision visual photometer which permits the luminance of the part of the surface of the moon unilluminated by the sun to be measured in terms of that of the illuminated part. The former is due to light reflected from the earth and is the only means of observing one term in the energy balance sheet of the earth, being a measure of energy not absorbed in the atmosphere or the surface. An image of the moon is divided by a beam splitter and the two resulting images juxtaposed so that the luminance of the limb unilluminated by the sun can be equated to that of the illuminated limb after attenuation by a neutral wedge. Calibration means are provided. J. M. W.

665. Receptors for physical photometry. 535.24

C. ROY-POCHON, *Lux*, **26**, 69-71 (*July-Sept.* 1958) and 94-96 (*Oct.-Nov.* 1958). *In French.*

A brief review of the characteristics of photo-emissive and photo-multiplier cells which are of interest to photometrists, with some of the precautions to be observed in their use. The second article deals with photo-conducting cells, germanium photo-diodes and photo-transistors and photo-voltaic cells comparing the different types. J. M. W.

535.24

666. Characteristics and applications of photo-electric cells.

F. A. BENSON, *Trans. Illum. Eng. Soc.* (*London*), **23**, 127-142 (No. 3, 1958).

The operating characteristics of photo-emissive, photo-voltaic, photo-conductive and photo-transistor cells are described, particular attention being given to photo-emissive cells, including photo-electric multipliers. Numerous applications of photocells in science, medicine and industry are briefly mentioned. A comprehensive series of references and a bibliography are included. P. P.

LAMPS AND FITTINGS

621.329

667. Design and application of a new high frequency power source for fluorescent lighting.

W. H. JOHNSON, J. L. WINPISINGER and J. F. ROESEL, JR., *Illum. Engng*, **54**, 43-49 (*January*, 1959).

Reduced control gear size, weight and power losses can be achieved by operating fluorescent lamps from a high-frequency power supply. The high-frequency converter should preferably be static rather than rotary (minimising maintenance), noiseless and of high efficiency. Such converters, operating from a 3-phase AC supply, have now been developed using transistors rather than the more conventional thermionic values. The ultimate intention is to develop a converter small enough to operate individual lamps. For the present, converters have been developed operating lighting loads of 1½ and 3 kW with an increase in overall efficiency of 15 per cent compared with normal supply frequencies. P. P.

621.327.43

668. Influence of electrode materials on fluorescent lamp discoloration.

A. W. WAINIO and F. M. CRAVEN, *Illum. Engng*, **53**, 615-619 (*Nov.*, 1958).

Discoloration of the ends of fluorescent lamps can take the form of end bands or diffused or well defined spots. The factors producing discoloration are considered, sputtering of the electrode material being a major cause. By replacing conventional nickel or nickel-plated iron lead wires and ones made of black-plated iron (iron electroplated with chromium and vanadium), considerable improvement in spotting has been obtained, but sometimes at the expense of increased end banding. P. P.

669. Circuits for short-arc lamps. 621.325

T. C. RETZER, *Illum. Engng*, **53**, 606-610 (*Nov.*, 1958).

Single-ended low-pressure short-arc mercury vapour discharge lamps can only be started cold. On the other hand, corresponding high-pressure lamps with diametrically-opposed current carrying leads can be re-started hot by a high-voltage pulse. The starting circuit should be capable of giving 10-20 pulses per half cycle at 50,000 volts. Similarly, high-pressure mercury-xenon and xenon short-arc lamps can be started at all temperatures with a high-voltage pulse circuit. P. P.

621.325

670. Effects of high operating temperature on the lamp envelope.

F. A. LOUGHRIDGE, *Illum. Engng*, **53**, 662-624 (*Nov.*, 1958).

The failure of mercury vapour lamps with soda-lime glass outer bulbs has been examined and has been found to be partially caused by physical deterioration of the glass. After approximately 2,000 hours of burning the outer surface of the bulb develops small fissures or cracks together with "weathering" of the glass constituents. Treatment of

the glass with sulphur dioxide retards but does not prevent the failure. Boro-silicate or other hard glass alone should be used in mercury lamp design. P. P.

621.329

671. Design and production of glassware for lighting.
D. SHELLSHEAR and C. D. CARTWRIGHT, *Trans. Illum. Eng. Soc. (London)*, **23**, 211-222 (No. 4, 1958).

A step-by-step description of the manufacture of blown glassware for lighting fittings is given, and includes references to techniques for shaping and for introducing decorative effects. The history of glassware fittings design is followed through from the first World War, an impetus to good design being given by the "Britain Can Make It" exhibition and the "Festival of Britain." The introduction of Swedish satin-etched glassware and German blown glassware in 1954 provided an incentive for closer co-operation between glassworks and designers in this country. P. P.

LIGHTING

628.972

672. Terminal City. Aerial gateway to the United States.
Illum. Engng. **53**, 522-535 (*Oct.*, 1958).

The lighting of the International Arrival Building (including the facilities for foreign-flag airlines) and of the Fountain of Liberty in the central area of New York International Airport (Idlewild) is described by the illuminating engineers responsible for the various projects. P. P.

673. The running costs of lighting installations. 628.93
F. GJESTLAND, *Ljuskultur*, **30**, 83 (No. 3, *July-Sept.*, 1958). *In Norwegian.*

A detailed summary of the factors governing the relative costs of lighting with different types of light source. R. G. H.

674. Lighting at the Brussels 1958 Exhibition. 628.97
A. BOEREBOOM, *Trans. Illum. Eng. Soc. (London)*, **23**, 148-160 (No. 3, 1958).

A feature contributing largely to the success of the Brussels 1958 Exhibition was the lighting. The electrical distribution system necessary to achieve this is described, as also are the techniques and equipment used for lighting the pavilions, various outdoor features and the illuminated fountains. Numerous photographs accompany the descriptions. P. P.

675. Lighting in Finland. 628.93
E. PAIVARINNE, *Trans. Illum. Eng. Soc. (London)*, **23**, 163-171 (No. 3, 1958).

The formation of a Lighting Society and the introduction of the fluorescent lamp into Finland in 1947 jointly marked the commencement of that country's post-war approach to artificial lighting applications and techniques. The advances that have since been made are illustrated by photographs of a recent office, school, factory and hospital. Two characteristics which distinguish Finnish lighting practice from that in this country is the marked preference for 40-watt fluorescent lamps and the wide use of specular reflectors. P. P.

676. Lighting and architecture. 628.972
G. GRENFELL BAINES and A. L. HOGG, *Trans. Illum. Eng. Soc. (London)*, **23**, 201-206 (No. 4, 1958).

An inappropriate mode of lighting or choice of lighting fitting can destroy an architect's conception of the interior appearance of a new building. This is particularly the case with the "lean and clean, spare and bare" lines of present-day buildings, whose effectiveness is more than ever dependent on suitable natural and artificial lighting. Only by early collaboration between the architect and the lighting engineer can such pitfalls be successfully avoided. P. P.

677. Character and compromise in hotel lighting. 628.972
C. DYKES BROWN and W. R. STEVENS, *Trans. Illum. Eng. Soc. (London)*, **23**, 179-198 (No. 4, 1958).

First impressions of a hotel, or even of the district or country in which it is situated, are very often given by the hotel lighting. This lighting largely determines the character of a hotel, but in practice compromises have to be made when catering for many types of guest and in providing an installation which will give relatively trouble-free maintenance. The lighting of areas of a hotel used by the guests and by the staff are separately considered, with recommendations for illumination levels and wattages of tungsten and fluorescent illuminants. An appendix describes a design approach based on considerations of apparent brightness. P. P.

678. School lighting in the U.S.A. 628.977
G. PLEIJEL, *Byggmästaren*, **37**, 70-72, A3 (1958). *In Swedish.*

The chief differences between American and European concepts of school lighting is that in the U.S.A. the economic aspects are given only secondary consideration. Daylight levels are not subject to regulation, but special care is taken to eliminate glare and reduce excessive brightness contrasts. Contrasts have been standardised as 1 : 10 maximum between room surfaces and visual task, minimum 1 : 1½. Detailed studies with models have been made of different types of transparent materials, such as glass blocks. A technique much favoured is the use of large areas of diffusing glass block mounted high, combined with low panels of clear glass "vision strip." Sometimes the glass block has strong directional characteristics in order to refract sunlight up on to the ceiling to avoid glare. R. G. H.

679. A symposium on schools. 628.92
Byggmästaren, **37**, 45-69 (A3, 1958). *In Swedish.*

Detailed photographs and drawings are given of a series of new schools in Sweden, which are of interest particularly for their solution of daylighting problems. R. G. H.

680. 10,000 footcandles for sunlight tests. 628.97
Electrical Construction and Maintenance, **57**, 77-79 (*Sept.*, 1958).

Describes the construction of a sunshine test cabinet for controlled sunshine exposure tests and experiments on photographic films and other film products, as used by the Eastman Kodak Co. of Rochester, N.Y. Details are given of the lighting arrangement, using fluorescent and incandescent, and the air conditioning system. The belief is expressed that a cabinet producing 20,000 lm/ft² could be produced should there be the need. W. R.

Some Notes on Answers to the 1958

City and Guilds Examination Papers

By S. S. BEGGS,
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Part II FINAL GRADE

In the Final Grade examination, the candidate is expected to be conversant with the application of his basic technology to lighting practice (on the measurement, design, manufacture or installation side as the case may be), and to be able to carry out more difficult calculations. Reasonable knowledge of practical equipment and installations is required. However, in any answer it is more important to indicate the reason for a particular construction or course of action than to give a wealth of detail (however accurate) which represents only one possible variation of the fundamental theme ; for the examiner is not so much interested in the candidate having read of or seen and memorised the particular feature contained in the question, but rather in his ability to analyse the situation and apply his basic knowledge to solving this (or any similar) problem.

First Paper

1 *Describe the phenomenon of electro-luminescence. Illustrate your answer with a sketch of an electro-luminescent panel and give a brief description of one application.*

Classically the term electro-luminescence refers to the production of light directly from electrical power, not involving heating of the source to incandescence. Within the last few years, however, it has been applied particularly to luminescence of material (normally a layer of specially prepared crystalline phosphor) caused by the application of a varying high potential gradient. [See paper by Bowtell and Bate, Trans. Illum. Eng. Soc. (London), Vol. **20**, p. 223 (1955).]

The electro-luminescent cell is usually in the form of a capacitor (see Fig. 5), of which the dielectric is a thin layer (about 0.1 mm thick) of a suitable phosphor (e.g. zinc sulphide) embedded in a translucent resin, and the "plates" are the one a glass plate, one face of which is made electrically conducting by chemical treatment, and the other a metallic layer applied to the resin; the field strength is of the order of 20,000 volts per cm. The light output increases rapidly with the applied voltage and with the frequency of the alternating field; a luminance up to 100 ft lamberts can be obtained (if short life is acceptable), but in practice the efficiency is low (not more than 10 lumens of green light or 3 lumens of white light per watt at most). So the application is only to rather specialised purposes, in which low efficiency is acceptable and a high light output is not required; examples are for indicator and instrument lighting, or in photographic darkrooms.

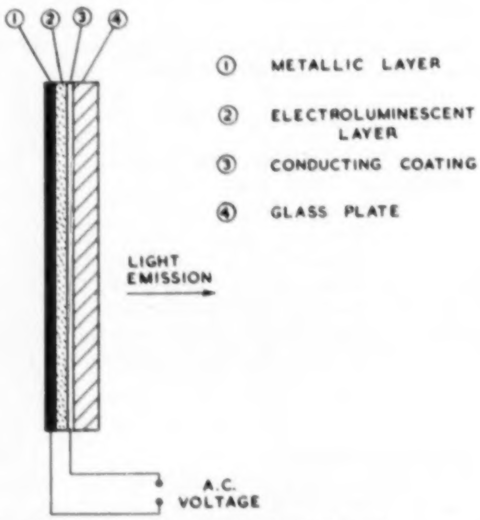

Fig. 5. Construction of an electroluminescent panel.

2 *In Great Britain the general service tungsten filament lamp is rated to have a life of* 1,000 *hours. Discuss the reason for this choice of life, and by making reasonable assumption regarding costs, consider whether the consumer would be better served if some other life were chosen.*

The light output and luminous efficiency of an incandescent filament lamp increase with increase in filament temperature,

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The intermediate grade papers were dealt with in the March 1959 issue of *Light and Lighting*.

but the life of the lamp decreases very rapidly. If energy is cheap relative to the cost of producing and installing the lamp, high luminous efficiency is of less importance than long life of lamp, and *vice versa*. For general lighting service the optimum life is that for which the cost of the light (e.g. per 1,000 lumen-hours) is a minimum. (The cost of installing the lamp may be a major factor, e.g. if it involves the use of scaffolding or a tower-wagon; and the undesirability of inconvenience, even in a domestic situation, must not be overlooked.) For the majority of applications 1,000 hours appears to be a suitable length of life.

If the cost of energy is p pence per kWh, and the cost of the lamp (to buy and install) is (P.W) pence, it is easy to show that the cost per thousand hours of use is $(p+\mathrm{P}/\mathrm{L}).\mathrm{W}$ pence, where L is the life of the lamp in thousand hours and W is its power consumption in watts. If the luminous efficiency is E lm per watt, the cost per thousand lumen-hours is $(p+\mathrm{P}/\mathrm{L})/\mathrm{E}$ pence. Now, the life of a gasfilled tungsten filament lamp is approximately inversely proportional to the seventh power of its luminous efficiency, so we may write $1/\mathrm{E}=k\,\mathrm{L}^{1/7}$, where k is a constant. Hence the cost of the light is $k(p+\mathrm{P}/\mathrm{L})\mathrm{L}^{1/7}$ pence. By differentiation this can be shown to have a minimum value (varying L) when $\mathrm{L}=6\mathrm{P}/p$. It is difficult to assess exact values for P and p in practice; but, allowing for the cost of installation, P is probably usually about $\frac{1}{3}$, and on the average p is about 2. Thus the most economical value of L is about unity, i.e. a lamp life of about 1,000 hours. (Note that in particular cases a different value of L might be more economical, but even in extreme cases this is not likely to vary by more than a factor of 2 either way, which is equivalent to a 5 per cent change in nominal voltage.)

3 *Four uniform line sources, 5 ft long, are arranged vertically at the corners of a horizontal plane 6 ft square. The output of each source is* 3,000 *lumens. Determine from first principles, either rigidly or to a reasonable approximation, the illumination on the plane at the centre of the square.*

It is intended that the formula for the illumination on a small plane element at right angles to a line source and opposite one end of it should be derived mathematically (rigidly). The formula is $\mathrm{E}=\mathrm{I}\sin^2\alpha/2d=(\mathrm{I}.l^2)/2d\,(l^2+d^2)$, with appropriate values for the symbols I, α, l and d. Here, for each source, $\mathrm{I}=3000/(5\,\pi^2)$, $l=5$ and $d=3\sqrt{2}$; whence $\mathrm{E}=4.17$. The required illumination value (from the four sources) is therefore 16.7 lm/sq. ft.

If one's mathematical ability does not extend to integral calculus (as it should), a reasonable approximation may be obtained by treating each line source as five separate one-foot lengths, and replacing each of these relatively short lengths by a "point source" placed at its centre and having the same "sine" light distribution about the vertical axis. The illumination E at the centre of the square from the point source at height h ft above the plane is $\mathrm{I}(\sin\theta.\cos^3\theta)/h^2$, where θ is the angle to the vertical of the line joining these points, so that

$$\sin\theta.\cos^3\theta=3\sqrt{2}\,h^3/[h^2+(3\sqrt{2})^2]^2$$

The illumination from each source is obtained by giving h the values 1/2, 3/2, 5/2, 7/2 and 9/2 in turn and summing the calculated values of E; that is the sum of the values of $(3000/5\,\pi^2)[24\sqrt{2}\,\mathrm{N}/(\mathrm{N}^2+72)^2]$, for $\mathrm{N}=1, 3, 5, 7$ and 9, which equals 4.21. Thus the calculated approximate value of the illumination from the four line sources would be (4×4.21) or about 16.8 lm/sq. ft. (It is interesting to compare this result with the value calculated from the precise formula above.)

4 *Discuss the problem of computing discomfort glare in a lighted interior. Explain one theoretical means for assessing discomfort glare, and show that in an interior lighted by diffusing opal spheres, the glare will be increased as the number of units is increased.*

Reference should be made to the work of Harrison and Meaker, Hopkinson and Petherbridge, Luckiesh and Guth, Vermeulen and de Boer, and the proposals of Logan and of Ainsworth. (See Stevens, "Principles of Lighting," chapter VIII, for a summary.) The assessment of discomfort glare by any one of these methods should be discussed in some detail.

The final part of this question raises one of the most tricky problems in illuminating engineering (I am sure unintentionally, for the examiner might equally well have referred to increase in the power of the lamps used in the spheres, which would have led to an unequivocal answer). Laboratory experimental work with an artificial field of view in which the area and luminance of the sources and the uniform luminance of the background could be controlled (independently) and measured precisely would lead one to expect the discomfort glare to decrease (or at best be unaffected) with increase of the number of diffusing spheres in the installation; yet the experiments of Harrison and Meaker in installations and experience in practice have indicated quite definitely that in most usual installations the discomfort glare would increase.

Study of the different formulae proposed for the assessment as a result of laboratory work suggests that a measure of the discomfort glare from a source of luminance B_s which subtends a solid angle ω steradian at the eye of the observer and is seen against a background of luminance B_b may be expressed in the form $\mathrm{B}_s^{2p}.\omega^q/\mathrm{B}_b^r$, where p, q and r are positive fractions (which may vary for different ranges) and $q < r$. For an installation the measure $\mathrm{G}\simeq\mathrm{B}_s^{2p}.(\Sigma\omega)^q/\mathrm{B}_b^r$, in which the sum $\Sigma\omega$ is that of the values for the individual fittings. Since $q \not> r$, if $\Sigma\omega$ and B_b are increased in the same proportion G decreases (or is unaltered if $q=r$). Harrison and Meaker's results are given in a form involving tabulated values, but when put (approximately) into this form would have values of q and r in which $q > r$; this therefore indicates an increase in the discomfort glare. The examiners probably had this formula in mind.

5 *Write a critical account of the problem of providing "artificial daylight," considering* (*i*) *the requirements,* (*ii*) *the means adopted to meet them,* (*iii*) *the practical fidelity obtained, and* (*iv*) *the economic aspect.*

The question of "artificial daylight" is discussed broadly in Stevens' "Principles of Lighting" or Walsh's "Planned Artificial Lighting." See also the paper on "Light Sources for Colour Matching" by Miles and Peach, Trans. Illum. Eng. Soc. (Lond.), Vol. **21**, p. 135 (1956).

The requirements may vary from a small local light (e.g. on a shop counter) to large "sky-lights" (e.g. for grading raw cotton or wool); and the closeness of the spectral distribution required may be only very approximate (e.g. to blend with and augment natural daylight) or very precise for exact matching of colours (as in paint manufacture or dyeing of fabrics). Light sources commonly used nowadays are filament lamps with correcting filter (blue glass bulb or Lamplough unit), tubular fluorescent lamps (of daylight or colour-matching grades), or a combination of a blue fluorescent tube with filament lamps, possibly with the addition of ultraviolet radiation for use with materials which have some degree of natural fluorescence; the Xenon arc discharge also is used in Germany. The size of source and diffusion of the light may be contributory factors, and constancy of the spectral distribution is usually important. The carbon dioxide tube,

which gives one of the best simulations of daylight, is no longer favoured because of its very low efficiency (about 2 lm/W). Tubular fluorescent lamps are likely to be most economic for large areas, on account of their high efficiency (40 to 50 lm/W); the use of filament lamps with filters (which can have only a low efficiency—less than 5 lm/W) is usually confined to small areas.

6 *Describe various ways in which light may be produced when gas is burnt in air, and comment on the relative efficiencies of the different methods. Exact figures are not required, but a reasonable comparison should be presented.*

The two basic practical ways are in the form of a luminous flame (in which the flame itself is the light source) and a non-luminous hot flame (in which the flame heats an object, which becomes the source of light). In the former case a gas of high hydro-carbon content is required, carbon particles in the flame being raised to incandescence to give light; in the latter case low hydro-carbon content is essential, or soot will be deposited on the object to be heated. The carbon particles radiate closely as a total radiator, at the temperature of the flame. Selective radiation characteristics in the object are an advantage in achieving high luminous efficiency, and this is the virtue of the Welsbach ceria-thoria mixture and its practical application in the gas-mantle. The higher the temperature the greater the luminous efficiency; the greater the proportion of primary air the more nearly complete the combustion of the gas-air mixture. A bunsen-type burner is therefore more efficient than a plain burner, and pre-heating of the mixture leads to a further improvement in efficiency. Since the velocity of flame propagation increases with air-gas ratio, not more than about half the desired amount of primary air can be entrained at low pressure or the flame "fires back"; at high gas pressure the velocity of the air-gas mixture is sufficient to prevent this happening and a high ratio can be used to obtain maximum efficiency. Approximate efficiencies of gas lamps in light output per cu. ft of gas of calorific value 500 B.Th.U. per hour are:—

(i) low pressure gas with open flame burner—25 lumens,
(ii) low pressure gas with inverted mantle—150 lumens,
(iii) low pressure gas with inverted mantle and pre-heating of air-gas mixture—200 lumens,
(iv) high pressure gas with inverted mantle and pre-heating of air-gas mixture—350 lumens.

7 *Discuss briefly the comparative importance of indirect general lighting, and of direct lighting with a number of adjacent sources, for four of the following tasks:—*

(i) *riveting of boiler shells,*
(ii) *operation of capstan lathes,*
(iii) *assembling of small mechanisms,*
(iv) *general drawing office work,*
(v) *dentistry,*
(vi) *typing and similar clerical work.*

Explain the principles involved, and indicate where local lighting is desirable in addition.

Indirect general lighting will give a very soft shadowless light, with minimum likelihood of glare, but with little modelling of solid objects and tending to make the precise location of objects difficult; the multiple-source direct lighting will tend to give high-lights and multiple (but not strong) shadows, excellent for revealing texture and form, but liable to give undesirable bright reflections in specular surfaces. The indirect diffused general lighting is therefore preferable for (iv) and (v), in which the main considerations are avoidance of bright reflections and confusing shadows; and the multiple-source lighting is suitable for (i), (ii), (iii) and (vi), to reveal clearly form and location of objects, especially if the light sources can be arranged relative to the work lay-out (but the typewriters, etc., should not have highly polished parts). Local lighting will generally be desirable when the indirect lighting is used, to give one directional light to aid location (e.g. of drawing pen, or forceps) and penetrate cavities; it should not be necessary for the remainder except in awkward positions, or if the parts in (iii) are very small, requiring a high level of illumination on the work.

8 *A 1,000-watt floodlight projector has a beam defined by the following values about an axis of symmetry:—*

Degrees from axis	0	3	6	9	12
Thousands of candelas	200	160	100	25	10

Two such lamps are to be used to light a vertical surface 40 ft long by 20 ft, the centre of which is 25 ft above ground level. Given that the beam axes are to be normal to the surface and 20 ft apart, determine the siting and height of the mounting poles, if the illumination at the centre of the surface is to be half the maximum illumination. Determine also the value of the latter.

A likely solution is to have the floodlights level with the centre of the vertical surface and equidistant from this point. Suppose that each floodlight is placed d feet from the surface, and that the rays from each which fall (i) on the centre of the surface and (ii) on the point directly opposite the other floodlight make angles A and B respectively with the beam axis. Then the total illumination values at these two points are respectively $(2\,I_A \cos^3 A)/d^2$ and $(I_o + I_B \cdot \cos^3 B)/d^2$, where I_θ is the intensity in direction θ. It is desired that these two illumination values should be in the ratio 1: 2. Hence

$$4\,(I_A/I_o)\cos^3 A = 1 + (I_B/I_o)\cos^3 B.$$

If $(I_\theta/I_o)\cos^3\theta$ be plotted on rectangular co-ordinate paper for the given intensity distribution data for the floodlights, one can easily find pairs of values A and B to satisfy this equation. However, since $\tan A = 10/d$ and $\tan B = 20/d$, $\tan B = 2\tan A$; the pair of values which satisfy this additional equation must be selected. It is quite sufficiently accurate to proceed as follows. Since all the angles are small, B is closely equal to 2A, and so (I_A/I_o) is little different from $[(I_{2A}/I_o)+1]/4$. (I_A/I_o) must be greater than $\frac{1}{4}$, and so A less than about 8°. A few trials quickly show that A is just over $7\frac{1}{2}$°. Hence the floodlights can be mounted on poles at a height of 25 ft and at a distance ($10 \cot 7\frac{1}{2}$°), i.e. about 75 ft from the surface. The maximum illumination (opposite a projector) is then about 36 lm/sq. ft. *Note*:—The question as set is not uniquely determinate, for the projectors need not be mounted symmetrically; but the simplest lay-out (assumed above) is quite sufficient.

Second Paper

1 *Explain the terms colour temperature and brightness temperature. Draw a colour triangle, and on it sketch* (i) *a locus curve for a full radiator over a temperature range from 1,000° to 2,000° C,* (ii) *a similar curve for a tungsten filament. The representation need not be exact, but should be in reasonable proportion. Comment on the differences and the general form of the curves.*

Colour temperature is that of a total radiator which emits light matching that of the given source. Brightness temperature is that of a total radiator which has the same luminance at a selected wavelength (usually in the red region) as the given source. Both measures are intended to give in one figure and

by a simple measurement an indication of the colour of the light from the source; neither should be applied to light of spectral distribution greatly different from that of a total radiator or the colour-rendering quality will be erroneously represented by the implied equivalence.

The colour triangle and "black body" locus are given in many textbooks. (See for example the books by Walsh or Stevens). Over the visible range of the radiation spectrum an incandescent tungsten filament radiates approximately as a "grey" body, i.e. with nearly constant emissivity, actually decreasing slightly with increase in wavelength; so its light closely matches that of a total radiator at a slightly higher temperature (by about 50°K). The curve for the tungsten filament will therefore be the same as for the total radiator, with the temperature scale decreased by this amount.

2 *Prove that a circular concave light source of uniform luminance is equivalent to a disc defined by its edge.*

The crater of the positive carbon of a low-intensity arc is concave, with a radius of curvature of 5 mm, and its perimeter is circular with a radius of 3 mm. The luminance is constant at 170 cd/mm². Construct a polar curve of luminous intensity for the source, explaining fully the steps in the process and the reasons for taking them.

(i) The first part is simple textbook work, and applies to any shape, not only circular. It follows easily from the symmetrical expression for the flux dF from a small area dA of luminance B falling on another small area dA′ at distance d, the normals to the areas making angles θ and θ' with the line joining them, *viz*. $d\mathrm{F} = \mathrm{B}.d\mathrm{A}.d\mathrm{A}'.\cos\theta.\cos\theta'/d^2$. The illumination on the second element dA′ is $d\mathrm{F}/d\mathrm{A}' = \mathrm{B}.\cos\theta'$. $(d\mathrm{A}\cos\theta/d^2) = \mathrm{B}.d\omega.\cos\theta'$, where $d\omega$ is the solid angle subtended by the luminous element dA at the centre of dA′. All elements of the same luminance B with perimeter defined by the cone $d\omega$, whatever their distance or inclination, produce the same illumination on dA′. By summation, finite areas of the same constant luminance and having their perimeters defined by the same solid angle about a point produce the same illumination on any surface at that point, and so are equivalent.

(ii) The arc crater is equivalent to a disc in the plane of its rim, of area $3^2.\pi$ sq. mm. and luminance 170 cd/sq. mm. The maximum intensity is therefore $(3^2.\pi.170)$cd., i.e. 4,800 cd., and the light distribution is symmetrical, the intensity at angle θ to the axis being 4,800 cos θ cd.

3 *Write explanatory notes on four of the following:—*

(i) *resolving power of the eye,*
(ii) *yellow/blue ratio,*
(iii) *after-images,*
(iv) *visual purple,*
(v) *photo-chromatic interval.*

Most of these are discussed fully in the textbooks. Briefly, for those who have no acquaintance with them, they are (i) the measure of the ability of the eye to separate the images of fine detail of high contrast; (ii) a measure of the normality of an observer's spectral sensitivity curve of vision, sometimes used in heterochromatic photometry, determined by his judgement of the relative transmissions for light of a specified colour temperature of standard yellow and blue liquid filters, which should have very closely equal values for the standard normal eye; (iii) the sensation of vision of an object or source of light after it has been removed from sight, due to fatigue of the retina, and may be positive or negative in character; (iv) a fluid contained in the rod elements of the retina (reddish purple in colour) which bleaches under the action of light, and thereby believed to stimulate the sensation of sight in the eye, the spectral absorption and rate of bleaching being very similar to the scotopic luminosity curve; (v) the range of intensity levels between the lower limit of visibility of light of a given colour and the threshold of ability to recognise the colour, which varies for different colours, and is considerable (a ratio of the order of 100 for the shorter wavelengths), except for red light.

4 *Prove that, with certain assumptions, a hollow sphere may be used as an integrating photometer, independent of the intensity distribution, position, or orientation of a contained source.*

Enumerate the assumptions, comment on their practical validity, and give some idea of the precautions needed to ensure reasonable fidelity in normal conditions.

This is the theory of the integrating sphere, and is given in textbooks on photometry. If the two elements dA, dA′ of the answer to Question **2** above lie on the internal surface of the sphere, $\theta' = \theta$, and $d = 2r\cos\theta$, where r is the radius of the sphere; hence the illumination on $d\mathrm{A}' = \mathrm{B}.d\mathrm{A}/(4r^2,)$ and if dA is a uniform diffuser (so that B is constant) this is the same wherever dA′ is on the sphere. Thus light diffusely reflected from any point of the sphere is spread uniformly over the interior surface. The luminance of the surface due to *reflected* light is therefore proportional to the total light output of the contained source, and is independent of the position, orientation or light distribution of this source.

The main assumptions are that (i) the interior surface of the sphere is a uniform diffuser of constant reflectivity over the whole surface and for all wavelengths (ii) the light source, its support and any screen (to exclude direct light) inside the sphere do not interfere with the distribution of reflected light (iii) the loss of light through any aperture or window by which the luminance of the interior is measured is negligible, and if the window is glazed it is non-selective. With care a good approximation to these requirements can be attained, and any error is small if the composition and distribution of the light is similar for the test and calibration sources. The practical form and photometric procedure should be discussed.

5 *According to Wien, the intensity of radiation E_λ at a wavelength λ from a source at an absolute temperature T obeys the law $E_\lambda = A.\lambda^{-5}.e^{-B/\lambda T}$, where A and B are constants. Show that this results in Stefan's law, and state the limitations which restrict the application. Deduce also an expression for the wavelength for maximum E_λ at any value of T.*

(i) The total radiated energy E is given by

$$\mathrm{E} = \int_0^\infty \mathrm{E}_\lambda.d\lambda = \int_0^\infty \mathrm{A}.\lambda^{-5}.e^{-\mathrm{B}/\lambda\mathrm{T}}.\,d\lambda$$

By the substitution $-\mathrm{B}/\lambda\mathrm{T} = x$, and so $d\lambda = (\mathrm{B/T})\,(dx/x^2)$,

$$\mathrm{E} = \int_{-\infty}^{0} \mathrm{A}.\left(-\frac{\mathrm{T}x}{\mathrm{B}}\right)^5.e^x.\left(\frac{\mathrm{B}}{\mathrm{T}}\right)\frac{dx}{x^2} = \int_{-\infty}^{0} -\mathrm{A}\left(\frac{\mathrm{T}}{\mathrm{B}}\right)^4.x^3.e^x.dx.$$

Integrating $x^3.e^x$ by parts gives $e^x(x^3-3x^2+6x-6)+$ constant; this over the range $-\infty$ to 0 equals (-6). Hence $\mathrm{E} = 6\mathrm{A}(\mathrm{T/B})^4 =$ constant x T^4, which is Stefan's law.

(ii) Wien's formula is only approximately true, the exact expression being Planck's radiation formula. However, the error is negligible except for large values of λT; it is less than 1 per cent for λT not greater than 3,000 micron degrees.

(iii) Using the substitution indicated above, the expression for E_λ may be written $-\mathrm{A}(\mathrm{T/B})^5\,x^5\,e^x$. Differentiating with respect to x and equating to zero, the stationary value of E_λ occurs when $(x^5+5x^4)=0$, i.e. when $x=-5$, or $\lambda = -\mathrm{B}/(\mathrm{T}x) = \mathrm{B}/(5\mathrm{T})$. In the usual manner, by a second differentiation

(giving a negative derivative) it is easily shown to be a maximum.

6 *Write short notes on the following visual phenomena:—*
(i) *Von Kries Duplicity Theory,*
(ii) *Purkinje Effect,*
(iii) *Stiles-Crawford Effect,*
(iv) *Weber-Fechner Law.*

The candidate can find all these explained fully in Walsh's "Photometry." Briefly they are (i) the theory of the dual nature of the visual mechanism, related to the rod and cone elements in the retina, (ii) the change in the relative sensitivity of the eye to radiation of long and short wavelengths (red and blue) from extended sources as the intensity level is reduced, (iii) the variation in the contribution of different parts of the lens of the eye to the luminosity of the retinal image for cone vision, which decreases markedly with distance of the lens element from the optic axis, so that the image luminosity is not proportional to the pupillary area, (iv) the logarithmic relationship between the intensities of the visual sensation and of the light stimulus, formulated by Fechner from the general law of proportional minimum stimulus increments for sensation perception propounded by Weber.

7 *A simplified isocandela diagram for a street lighting source is shown in Fig. 6 below. The angle θ is measured from the downward vertical, the angle ϕ from the vertical plane parallel to the street axis. The other three quadrants are similar and there is no light above the horizontal. Use the diagram to determine approximately the total lumens emitted from the source, explaining your procedure.*

On the isocandela web equal areas represent equal solid angles, and the octant shown in the figure represents $\pi/2$ steradians. The diagram should be divided into small equal areas, e.g. by ruling on it lines at $\frac{1}{2}$ cm intervals both ways to superimpose a square mesh, from which the area of any region can be derived approximately by counting the number of squares in that region. If the total number of squares in the octant is N, the scale is clearly $2N/\pi$ squares to one steradian. If the number of squares enclosed between any two isocandela contours for intensities I_1 and I_2 and the sides of the diagram

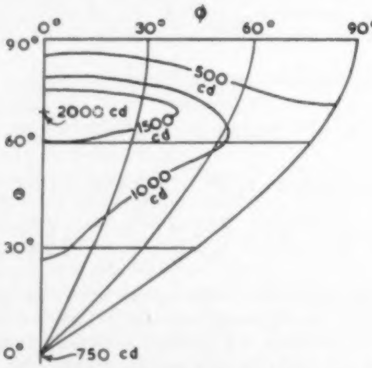


Fig. 6. Isocandela diagram for a street lighting source.

is n, the solid angle of this zone is $\pi n/2N$ steradian, and the average intensity may be taken as a little under $(I_1+I_2)/2$ candelas; hence the flux in this zone is approximately $(I_1+I_2)\pi n/4N$ lumens. By calculating this product for each pair of isocandela lines and summing the values, the total flux in the octant is obtained; since the distribution is axially asymmetrical and there is no light emitted above the horizontal, this sum is one quarter of the total light output of the source. The answer obtained should be about 5,500 lumens.

8 *Describe briefly one method of measuring each of two of the following:—*
(i) *transmission factor of a neutral filter,*
(ii) *luminance of a diffuse reflecting surface,*
(iii) *distribution of luminous intensity of a narrow-beam floodlight.*

Suitable photometric methods are described in Walsh's "Photometry." The transmission factor of a neutral filter is best obtained by the use of a photometer bench, the desired factor being the ratio of measurements made with and without the filter in position. The luminance of a diffusing surface is most easily determined by making a measurement with a visual illumination photometer, as though the surface were the test plate; the true luminance (in ft lamberts) is the reading obtained (on the lm/sq. ft scale) multiplied by the reflection factor of the test plate with which the instrument was calibrated. The special consideration in the measurement of intensity distribution of a narrow-beam floodlight is to ensure that the photometer is at sufficient distance from the floodlight for the beam to have been completely formed, i.e. beyond the point at which rays from the edge of the reflector or lens cross the beam axis; for less distances the application of the inverse square law leads to serious error.

Third Paper

1 *In a room 50 ft long by 30 ft wide and 20 ft high it is required to achieve the following distribution of luminance:—*

Ceiling	*3 ft-L.*	*Long walls*	*7 ft-L.*
Short wall	*10 ft-L.*	*Short wall*	*5 ft-L.*

These values are to include both direct and inter-reflected light. The illumination of the floor is to be 10 lm/ft². The reflection factor of the ceiling is 70 per cent, of the walls 40 per cent, and of the floor 10 per cent. By estimating the reflected light contribution, derive the required direct light contribution for each surface. Hence estimate the total flux required for the light sources to be used in the installation. Note: Exact calculations are not required; reasonable approximations which would provide a working basis for a lighting scheme should be made.

This question is the essence of the calculation involved in the design of the visual field, when the desired luminance of each surface has been determined. (See paper by Waldram, Trans. Illum. Eng. Soc. (London), Vol. **23**, p. 113 (1958)). The illumination on each surface (ceiling, wall and floor) received from each of the other surfaces (due to their luminance) must be estimated; the total illumination required on each surface (of known reflection factor) to produce the desired luminance must also be determined. The difference between these two quantities (for each surface) is the illumination required by direct light from the sources; this figure multiplied by the area of the surface to which it applies gives the total direct flux required for that surface, and the sum of these values for all the surfaces gives the total light output of the sources required.

Only very approximate calculations need be made. (See Stevens', "Principles of Lighting," Appendix 5, Section 6). Consider first the illumination at the centre of the floor. If the rectangular ceiling be replaced by a circular disc of equal area (or better still each half by a circular disc), applying the easily remembered formula for the illumination from a disc on a parallel surface (viz. $E=\frac{1}{2}.B\,(1-\cos\alpha)$, if **B** is in ft lamberts

and α is the angle subtended at the point by the diameter of the disc), the illumination due to the ceiling is found to be approximately 0.5B, i.e. 1½ 1m/sq. ft. Now, if the walls were of the same luminance as the ceiling, the walls and ceiling together would provide illumination B 1m/sq. ft (from the formula for a diffusing hemisphere), and the walls themselves therefore (B—0.5B) i.e. 0.5B. The contribution from each wall would be closely in proportion to the plan angle which it subtends at the centre of the floor, which may be taken as approximately proportional to its length; hence the long walls would contribute 0.5B x (5/16) and the shorter walls 0.5B x (3/16) each, say 0.15B and 0.1B respectively. In the present case the long walls therefore contribute approximately 1 1m/sq. ft each and the two different shorter walls 1 1m/sq. ft and ½ 1m/sq. ft. Thus the total illumination at the centre of the floor by light reflected from walls and ceiling is 5 1m/sq. ft. Since the illumination required is 10 1m/sq. ft, the light sources must supply (10-5) i.e. 5 1m/sq. ft direct illumination, and (since the floor area is 1,500 sq. ft.) a total of 7,500 lumens to the floor.

The same method can be applied to the other surfaces in turn. Note that the luminance of the floor must be (10×0.1), i.e. 1 ft lambert; also the total illumination of each of the other surfaces must be its luminance divided by its reflection factor. The results of the calculations are shown in tabular form below:

Calculated values of illumination and luminous flux

	Floor	Ceiling	Long Wall	Brighter Short Wall	Darker Short Wall
Total illumination (1m/sq. ft)	10	4	17½	25	12½
Reflected illumination (1m/sq. ft)	5	4	4½	5	5½
Direct illumination (1m/sq. ft)	5	0	13	20	7
Area (sq. ft)	1,500	1,500	1,000	600	600
Luminous flux (lumens)	7,500	0	13,000	12,000	4,000

Total flux $= 7{,}500 + 2\ (13{,}000) + 12{,}000 + 4{,}000 \simeq 50{,}000$ lumens.

Therefore no direct light is required on the ceiling; direct illumination of the floor should be 5 1m/sq. ft, of the long walls 13 1m/sq. ft, and of the brighter and darker short walls 20 1m/sq. ft and 7 1m/sq. ft respectively. The total light flux from the light sources required is approximately 50,000 lumens.

2 *Describe the "line and bar" system of approach lighting as used at an international airport. What are the merits of this system? Describe briefly lighting apparatus used for it.*

This system and suitable types of equipment have been described in several papers. (See, for example, Stevens' "Principles of Lighting," chapter XIV and references). The main merits of the system may be summarised as: (i) good guidance as to the direction to proceed provided by the centre line, which in bad visibility conditions is more easy to follow than an off-set line parallel to the runway, (ii) fixture of the horizontal plane by the "horizon bars," which clearly indicates banking of the aircraft, and (iii) an unmistakable indication which will be interpreted correctly, quickly and instinctively.

3 *Explain, with sketches, the terms working-face and back-face in the design of prismatic refractors. Show how the choice between maximum intensity and maximum "pick-up" of light flux determines the prism arrangement, and discuss the influence of reflection at the air-glass and glass-air interfaces.*

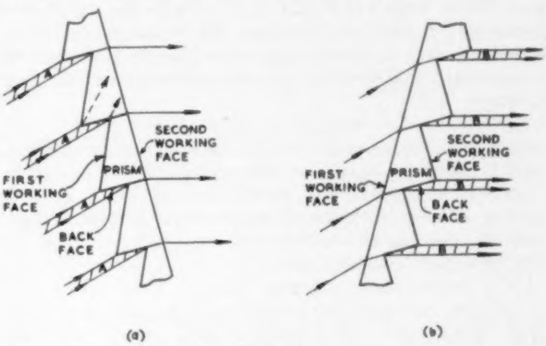


Fig. 7. Action of prismatic refractors.

(i) The working-faces of a prism are those designed to direct the incident light into the desired direction; the back-face is the return face which is the base of the refracting prism. Fig. 7 shows two arrangements of prisms on a refractor, of which the working-faces and back-faces are indicated.

(ii) The prisms are usually designed so that one surface of the refractor is smooth, and the back-face is made parallel to the rays between the first and second working-faces, in order to keep losses to the minimum. If the prisms are oriented so that the back-faces are on the side of the material presented to the incident light, as in Fig. 7 (a), no dark areas between adjacent prisms will be apparent in the emergent beam, and the intensity will be a maximum; but the light flux in the regions marked A falls on the back-faces, and is lost from the beam. If the back-faces are made on the side of the material remote from the incident light, as in Fig. 7 (b), no light flux is mis-directed, but dark areas (marked B) are apparent between the prisms, and the refractor does not give as high an intensity as one of the same size but with the prisms formed as in Fig. 7 (a). The relative importance of maximum intensity and light flux in the beam determines which form of refractor should be used.

(iii) Light reflected at an air-glass surface (the incident face of the refractor) is small for angles of incidence less than about 50° (producing a deviation up to about 20°), but increases rapidly thereafter with increasing angle of incidence, so that for angles greater than about 75° (producing deviation of about 35°) the proportion of light transmitted through the surface is of little value. Similarly, at a glass-air surface (the emergent face of the refractor), the loss by Fresnel reflection at the surface is small for deviations up to about 20° but is excessive for deviations above about 35°; the corresponding angles of incidence in the material are about 30° and 40° respectively. However, in some cases in which the rays may be directed in the desired direction by reflection, the angle of incidence in the material may deliberately be made greater than the critical angle (which is usually between 40° and 45°), and this surface be designed as a reflector (with no loss of light if it is optically smooth) to direct the light to emerge through either the back-face or the first working-face.

4 *For the lay-out of a street lighting scheme using non cut-off lanterns:—(a) Describe the construction and use of a siting gauge for planning for bends. (b) Explain the basic principles of siting at T-junctions and cross-roads.*

Discuss briefly how to plan an area of streets, showing that it may be necessary to depart from a rigid application of rules for planning.

Both the construction and use of a siting gauge and the principles of siting at T-junctions and cross-roads are fully described in the B.S. Code of Practice for Street Lighting, Part 1, Traffic Routes (CP 1004: Part 1: 1952); see also Stevens' "Principles of Lighting," chapter XII. The procedure for planning an area of streets and the modifications necessitated by practical considerations are also discussed in the same references.

5 *Describe carefully, with sketches, any one of the following pieces of lighting equipment with which you are familiar:—*
 (i) *A three-aspect railway signal light.*
 (ii) *A focusing spotlight (Fresnel lens type) for film studios.*
 (iii) *An operating theatre light.*
 (iv) *A coal-face lighting unit.*
 (v) *A theatre stage cyclorama unit.*

Discuss critically the requirements for the unit chosen and consider how well it satisfies these requirements, both optically and mechanically.

Examples of most of these pieces of equipment are described in published literature; reference may also be made to Stevens' "Principles of Lighting" and to the older book "Theory and Design of Illuminating Engineering Equipment" by Jolley, Waldram and Wilson. But the candidate should endeavour to describe and illustrate an article *with which he is familiar*, as the question asks him to do; and the degree to which it meets the optical and mechanical requirements of its function must also be discussed.

6 *An engineering shop assembling heavy vehicles such as tractors consists of six open-sided bays side by side, each 300 ft. long by 50 ft wide. A "north-light" roof construction is used, the lights running across the bays at intervals of 30 ft along the length, leaving a clear height of 40 ft between the floor and the lowest girder. A travelling crane can move along the whole length of the bay. The crane stretches right across the bay and its platform is 35 ft above the floor.*

Plan the artificial lighting for a single bay, explaining carefully the reasons for your suggestions; a scheme of decoration should be included. Make an estimate of the cost of operating the lighting, assuming the shop is in use for 24 hours a day for six days a week, and comment on the cost of maintenance.

There are many possible alternative schemes, and the student is recommended to study descriptions of installations in current periodicals, especially *Light and Lighting*. (See in particular Vol. 50, pp. 290 et seq., Oct. 1957.) HPMV lamps, either plain or fluorescent, might be used, or low pressure tubular fluorescent lamps; the size of the installation makes incandescent filament lamps impracticable. A general lighting scheme of fittings mounted from the roof trusses and serviced from the crane platform would be suitable; they could be separate fittings, or if tubular fluorescent lamps are used continuous troughing. Two rows of fittings per bay, running the full length, utilising 400-watt HPMV lamps at 15 ft spacing or twin-tube 80-watt fluorescent lamp units at half this spacing would provide an illumination of about 15 lm/sq. ft, which should be suitable for the class of work done. The relatively close spacing would ensure good illumination of vertical and inclined surfaces, and additional local lights should be unnecessary (except for the crane operator). Light coloured paint should be used for the decoration, maintenance of which should not be costly as the work is not dirty, and the fittings are accessible. However, long life lamps are desirable so that the crane (which is used to service the fittings) is not diverted from its normal work too frequently; a group replacement scheme would probably be advantageous, since the workshop is in use almost continuously. The factory is well-provided for natural lighting by day, and the artificial lighting may be assumed to be on about 4,000 hours a year; the lamps could be renewed annually.

Electricity tariffs vary considerably; one common system is a fixed charge proportional to the total load installed, with an additional low charge per unit of energy used. If a charge of £6 per annum per kVA installed and $\frac{5}{8}$ pence per unit used be assumed, for each bay the cost for energy per annum will be about £300 and for lamps about £100. This cost is not likely to vary greatly for different forms of the tariff. (*Note*: The values assumed and basis of the calculation for the particular installation chosen should be clearly shown in the candidate's answer.)

7 *The accompanying sketches (Fig. 8) show diagrammatically, and not to scale, a plan and sectional elevation of a ladies' shoe shop, the width of which is 20 ft. Entrance through a show window leads to a flight of stairs which in turn leads to the shop proper. There is also a flight of stairs leading to a basement selling men's and children's shoes. Both flights are 6 ft wide. In the upper shop the two long walls have racks for shoes. The end wall is to be used for a decorative treatment. Lines of chairs for customers are placed 5 ft out from the long walls and parallel to them.*

Plan a scheme of lighting and decoration for the ladies' shop and stairs, including suggestions for the end wall and for the treatment of the show window.

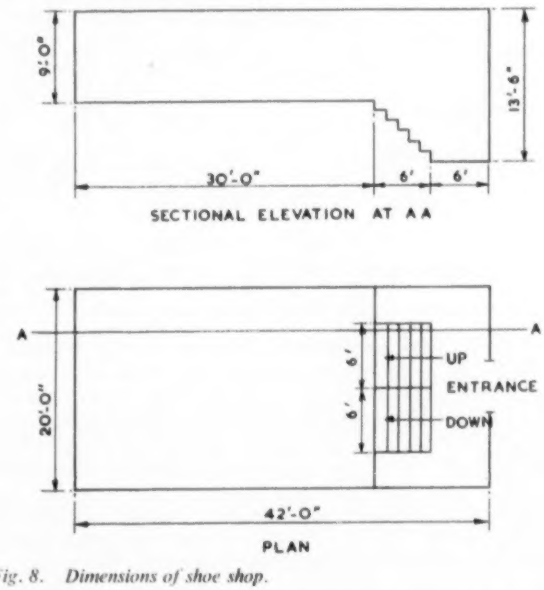


Fig. 8. Dimensions of shoe shop.

This question, like the previous one, permits of many different answers. Indeed, since a shop such as this should have distinctive character, the normal basic engineering requirements (such as efficiency and permanence) are subordinate to individual artistic and psychological preferences, and no "standard" solution can be given; this is essentially a question for the artist. However, some general points to be borne in mind are the desirability of making the entrance attractive, the need of good lighting for the staircases (which, however, must not distract from the display area), and the provision of a really good display on the end wall of the upper shop to draw customers right into the shop. (The value of such deep display areas has been proved in practice.)

Rows of equally spaced "off the shelf" general lighting fittings should be avoided, for they have no individuality. A luminous ceiling is a possibility for the entrance "window" area; pendant fittings must not be used because of the view of them from the upper shop and staircases. Alternatively, great use can be made of recessed spotlights and reflector-type filament lamps; down-lighting would then be particularly useful on the staircase. The entrance area should be striking, but level of illumination is a less important criterion than distinctive character of the lighting. The general illumination in the upper shop need not be high—10 lm/sq. ft is probably quite adequate—and use may be made of decorative constructions provided the seating area and the shoe racks are well illuminated by localised lights. Strong accent lighting is required for the region of the end wall, with perhaps small "picture frame" show pieces, a large stylised model shoe feature, or an appropriate mural.

A candidate is recommended not to attempt a question of this nature unless he has some artistic ability. However, much can be learned from studying modern shop-lighting installations, many of which have been illustrated in the pages of *Light and Lighting*.

8 *Four tubular fluorescent lamps, each 5 ft long, are mounted on a black ceiling to form a cross with the limbs at right angles and equal in length. Assuming that the lamps are perfectly diffusing cylinders, each emitting 3,000 lumens, calculate the direct illumination on a horizontal plane 10 ft below the point of junction of the lamps.*

The lamps are now backed by a uniformly diffusing disc 10 ft diameter of 70 per cent reflection factor placed symmetrically with respect to the lamps. Estimate the increase in illumination at the position previously considered. Reasonable assumptions and simplifications may be made provided they are justified. Reflection from walls and the remainder of the ceiling should be ignored.

(i) The exact formula (see textbooks) for the illumination at a point on a surface directly opposite one end of a parallel diffusing linear source (with appropriate values for the symbols) is

$$E = (I/2d)\,[\alpha + \sin\alpha.\cos\alpha] = (I/2d)\,[\tan^{-1} l/d + (l.d)/(l^2 + d^2)]$$

For the given sources $I = 3{,}000/(5\pi^2)$ and $d = 10$; hence for each source $E = 2.6$ lm/sq. ft, and from the four sources the illumination is closely 10.5 lm/sq. ft. (*Note*: If each linear source is replaced by a "point" source of the same intensity distribution located at its centre, the calculated total illumination will be closely 11 lm/sq. ft, which is a good approximation to the true value.)

(ii) The majority of the light emitted from the lamps above the horizontal falls on the ceiling within a few inches of the tubes; the reflected light may therefore be regarded as being radiated diffusely from a plane cross with limbs only a few inches wide and each about 5 ft long. The mathematical expression for the illumination immediately below the centre of this cross (but not for other points) is therefore identical with that quoted above for the diffusely radiating tubular lamps; the values of l and d may be taken to be the same as in the previous calculation, the only difference being in the value of I. Since the total light reflected from the disc per foot length of limb of cross is $(0.7 \times 1{,}500)/5$ lumens, the intensity per foot is $(0.7 \times 1{,}500)/(5\pi)$ cd. The factor I in the formula therefore now has this value (approximately) instead of the value $(3{,}000/5\pi^2)$ used previously, and these numbers actually are nearly equal. The illumination immediately below the centre of the cross is therefore just about doubled by the introduction of the white diffusing disc.

National Illumination Committee of Great Britain*

Report for the year 1958

There has been considerable activity among the various sub-committees in preparation for the Fourteenth Session of the International Commission on Illumination, which is due to take place in Brussels from June 15th-24th, 1959. The previous method of operation in the various subjects, whereby the secretariat country for each was responsible for the production of a full progress report, has now been superseded and only about half the subjects, i.e., those for which development has been of a routine nature, are now dealt with in this way. For the other subjects, where development is urgent or where international agreement is desirable, the idea of Working Committees was instituted in 1955, and will no doubt be renewed during the coming session. Numerous meetings have been held of these Working Committees, and for each subject a progress report will be presented in Brussels, as well as any special reports which have been prepared since 1955.

The first special report produced by a Working Committee for publication concerned Colours of Light Signals, and at the request of the Commission the British National Committee undertook to produce this document in printed form. It will be reproduced in the three official languages of the Commission (French, English and German) and will be available in the early part of 1959.

The secretariat of the subject of Lighting for Photography, Cinema, Television Production and Theatre Stages was entrusted to this country and the sub-committee under the chairmanship of Mr. W. R. Stevens has prepared the Secretariat Report. Of the Working Committees, four have chairmen from this country; they are: Colours of Light Signals (Mr. B. Boorman), Visual Performance (Mr. H. C.

* The NIC is affiliated to the International Commission on Illumination. This report was approved at the annual general meeting of the committee held on Thursday, January 29th, 1959.

Weston), Street Lighting (Mr. J. M. Waldram) and Aviation Ground Lighting (Mr. E. S. Calvert).

The NIC/CIE Panel has held two meetings and has dealt with numerous matters concerning the Committee's participation in the work of the CIE. Most of these have arisen through the continued publication by the Commission of its Bulletins; Nos. 5 and 6 have been issued during the year.

The Statutes of the Commission, which were issued as an Appendix to CIE Bulletin No. 4, have been considered, and a number of minor amendments have been proposed.

The question of papers for presentation in Brussels has again been actively considered, particularly in view of the fact that the CIE Papers Committee has indicated the intention of placing a severe restriction on the number to be accepted. The Committee set up an NIC Papers Committee, consisting of Dr. Stiles (chairman), Messrs. Higgins, Pott and Waldram, and five suggested papers were submitted. Of these, three were passed to the CIE Papers Committee and it is with pleasure that we report the acceptance of all three. The titles and authors are as follows:— "Adaptation and scales of brightness" by Dr. R. G. Hopkinson (Building Research Station); "Hospital lighting" by Mr. J. Musgrove (Nuffield Foundation) and Dr. W. J. W. Ferguson; "Natural lighting prediction and the design of window systems for tropical climates" by Mr. P. Petherbridge (Building Research Station). The total number of papers to be presented in Brussels is 24.

It has been agreed by the Committee that at the Brussels session the Leader is to be Mr. H. C. Weston, with Mr. W. R. Stevens as his deputy. In view of the responsibility devolving upon Mr. Weston, who is also one of the Committee's representatives on the Executive Committee of the Commission, it has been agreed that the other member, Mr. A. G. Higgins, shall put forward the view of the British National Committee at meetings of the CIE Executive Committee.

The Committee wishes to record, with regret, the fact that Mr. A. J. Bull has retired from the chairmanship of the Railway and Dock Lighting Sub-committee; Mr. H. E. Styles has been appointed in his place. Two resignations of members of Working Committees have also taken place; Mr. H. J. N. Riddle, a member of the Working Committee on Signal Lights, has been replaced by Mr. J. H. Devine, whilst Mr. G. W. Milburn has become a correspondent on the Working Committee on Lighting Education in Schools, in place of Mr. H. E. Dance.

Copies of the International Lighting Vocabulary, issued by the Commission, became available during the year, and about 70 copies have been disposed of in this country. It contains the definitions of some 530 terms in the official languages of the Commission.

The Committee has met on three occasions during the year, and it has received with pleasure the addition of the Society of Dyers and Colourists to the list of co-operating organisations; the representative of the Society is Mr. K. McLaren. It is with regret, however, that the Committee has to record the resignation from this list of the Independent Lamp Manufacturers' Export Group.

The Air Ministry is now represented by Mr. H. F. Innocent, in place of Mr. Kemp, whilst the Electricity Council has nominated Mr. E. C. Lennox as one of its representatives in place of Mr. Birt. Mr. D. G. Osborne now represents the Glass Manufacturers' Federation, in place of Dr. Preston, whilst Mr. Dance, of the Ministry of Education, has been replaced, as mentioned above, by Mr. G. W. Milburn. For the Ministry of Supply, Mr. E. G. Cooper is one of the representatives in place of Mr. Gibson. The Committee regrets, however, that it cannot any longer call on the services of Mr. J. L. Russell, who having been transferred to another sphere of activity, has ceased to be a representative of the Ministry of Supply; Mr. Russell has served in many ways in connection with the work of this Committee, which places on record its appreciation of his services.

S. English,
Chairman.
L. H. McDermott,
Secretary.

Constitution of Committee, December 31st, 1958.

Officers

Chairman: Dr. S. English.
Vice-Chairmen: W. R. Stevens, H. C. Weston.
Hon. Treasurer: E. B. Sawyer, British Lighting Council, Brettenham House, Lancaster Place, London, W.C.2.
Hon. Secretary: L. H. McDermott, National Physical Laboratory, Teddington, Middlesex.
Representatives of Great Britain on the Executive Committee of the International Commission on Illumination: A. G. Higgins, H. C. Weston.

Nominated by the Sponsoring Organisations

Illuminating Engineering Society: G. F. Cole, J. G. Holmes, E. C. Lennox, L. H. McDermott, J. M. Waldram.
Institution of Electrical Engineers: C. W. M. Phillips, H. R. Ruff, W. R. Stevens, Dr. J. W. T. Walsh, G. T. Winch.
Institution of Gas Engineers: J. B. Carne, A. G. Higgins, F. C. Smith, D. M. Thompson, W. H. Welch.

Nominated by the Co-operating Organisations

Admiralty: H. A. L. Dawson.
Air Ministry: H. F. Innocent.
Association of Public Lighting Engineers: N. Boydell, H. Carpenter.
British Electrical and Allied Manufacturers' Association: J. M. H. Stubbs.
British Electrical Development Association: J. I. Bernard.
British Lighting Council: A. G. Penny, E. B. Sawyer.
British Plastics Federation: Dr. W. E. Harper.
British Standards Institution: J. F. Stanley.
British Transport Commission: A. H. Cole (*British Railways*), H. E. Styles (*London Transport Executive*).
Building Research Station: W. Allen, Dr. R. G. Hopkinson.
Electricity Council: E. C. Lennox, M. D. Stonehouse.
Electric Lamp Industry Council: W. J. Jones, Dr. J. W. Strange.
Electric Light Fittings Association: J. H. Studholme, D. L. Tabraham.
Electrical Contractors' Association: A. H. Olson.
Gas Council: J. B. Carne, F. W. Sansom.
Glass Manufacturers' Federation: D. G. Osborne.
Institution of Municipal Engineers: C. Harper.
Medical Research Council: Dr. W. J. W. Ferguson, H. C. Weston.
Ministry of Education: G. W. Milburn, A. P. Pott.
Ministry of Health: D. A. Hughes.
Ministry of Labour and National Service: M. A. McTaggart.
Ministry of Power: J. Cowan, H. C. Lister.
Ministry of Supply: E. S. Calvert, E. G. Cooper.
Ministry of Transport and Civil Aviation: Dr. H. F. Gillbe, W. Hadfield, N. F. Hildyard.
Ministry of Works: W. E. Rawson-Bottom.
National Coal Board: R. Buffry, P. N. Wyke.
National Physical Laboratory: Dr. W. S. Stiles.
Nuffield Foundation: J. Musgrove.
Post Office: R. S. Phillips.
Road Research Laboratory: G. Grime.
Society of Dyers and Colourists: K. McLaren.
Society of Glass Technology: Dr. S. English.

I.E.S. ACTIVITIES

London

At the meeting held in London on March 10th a paper entitled "The Permanent Supplementary Artificial Lighting of Interiors" was presented by Dr. R. G. Hopkinson and Mr. J. Longmore, of the Building Research Station.

The paper opened by considering some of the problems involved in compact building. To make the most efficient use of an available site, especially in built-up areas, it is often necessary to build deep rooms with low ceilings. Such requirements conflict with modern demands for higher levels of illumination. New standards of daylight have matched increases in artificial lighting levels over the past 10 or 15 years and it becomes increasingly difficult to provide acceptable levels of daylight in these new buildings without causing excessive sky glare, excessive solar heat gain in summer and serious heat loss in winter.

The solution lies with combined daylight and artificial light, but it must be conceived and fully integrated with the design of the building resulting in a better all-round architectural and lighting solution than daylighting alone. When a room is lit entirely by daylight much of its character is determined by the design and position of the windows. If certain levels of daylight factor must be achieved, the architect is constrained by the geometry but if he can design the windows for appearance and proportion supplementing the daylight by well placed artificial sources, he has a greater freedom of expression and can pay more attention to ensuring good seeing conditions and absence of sky glare.

A room which is inadequately lit by daylight poses two problems. First, there is the need to provide extra light to enable work to be done efficiently, and second, there is the need to brighten up the gloomy parts of the room; gloomy not necessarily because they receive little illumination but because they are subjectively dark by contrast with the view of bright sky.

The second problem is at least as important in practice as the first and to meet a lack of experimental data a study was made to determine the levels of supplementary lighting necessary to provide a balance of brightness with the daylighting. Scale model rooms were constructed and a team of observers made judgments of acceptable levels of artificial illumination. A number of variables connected with the design of the supplementary lighting were studied: (1) the effect of varying sky luminance on the level of supplementary lighting; (2) the effect of the design and size of the window; (3) the effect of changes in the reflection factors of the interior surfaces; (4) the effect of position in the room of the supplementary lighting.

These experiments established some basic principles. Supplementary lighting must be of a sufficiently high level to effect a balance of adaptation between the brightly lit parts of the room near the window and the artificially lit parts of the room remote from the window. This high level is determined not only by the visual tasks to be undertaken in the room but by the subjective sensation of adequacy of brightness. The level of supplementary lighting is related to the daylight factors and brightnesses of the surfaces at the front and back of the room and to the size of the window. The level required to provide the best balance of brightness with daylight varies in proportion to the luminance of the sky. The level of light necessary for an overall satisfactory solution, free from gloom or excessive shadows, may be high and more or less independent of the sky luminance, because on dull days there is a need not only to balance the window brightness but to enliven the appearance of the whole room.

The results obtained so far indicate that, for the type of room under consideration, by providing 40 lm/ft^2 of supplementary light at the back of the room it is possible to achieve an acceptable balance for a range of sky luminances from dull winter skies of about 500 ft. lamberts to bright summer skies of about 4,000 ft. lamberts.

The spectral quality of the lighting should be chosen so that the least irritation is caused to users by obvious differencies between colours seen under daylight and under the artificial illuminant. Daylight varies very much in quality, especially when sunlight blends with the light from a blue or a cloudy sky. The presence of supplementary lighting introduces a constant reference standard, not normally present, so that these variations in the quality of the daylighting may be more noticeable. Only experience will tell if they are troublesome.

Manchester Centre

On February 12th, Mr. W. Imrie-Smith presented a paper entitled "Analytical Approach to Industrial Lighting." "To provide suitable and sufficient lighting which would be easy on the eye and allow the seeing task to be performed with the minimum of nervous strain." This, Mr. Imrie-Smith stated, was the avowed object of the lighting engineer.

To be solved successfully, each problem must be approached analytically, giving due consideration to the building plan layout and general surroundings, as well as making a careful appreciation of the actual seeing task. Following the efforts in the past to provide sufficient light there is a tendency today to consider most problems solved by providing a general lighting layout without consideration of these additional factors. After reviewing the choice of light sources available, Mr. Imrie-Smith demonstrated the effect of the illumination of the visual field on accuracy of perception and the importance of the brightness levels surrounding the point of concentration. The slides used were carefully chosen to illustrate particular points and covered a wide range of installations where layout of reflectors and direction of illumination to provide a successful solution had been arrived at by a careful analysis of the problem.

Mr. Heslop and Mr. Robinson opened the discussion, and a vote of thanks was proposed by Mr. Wilcock.

Leicester Centre

Mr. S. Penn Smith, F.R.I.B.A., the Leicester Architect, was the lecturer at the meeting of the Leicester Centre held on Monday, March 23rd. His subject was "An Architect Looks at Lighting" and in his opening remarks, Mr. Penn Smith suggested that an architect was a "Jack of all trades" and whilst he should have some knowledge of lighting technique, he was not a specialist.

The audience was greatly interested in the lantern slides which had been made of some of the larger civil, industrial and commercial buildings, Mr. Smith had seen, during his tour of the United States. Mr. Smith was of the opinion that American architecture and lighting was designed to be sensational and put over by showmanship, but in actual fact in the majority of cases, these elaborate schemes lacked finish and he felt that British architecture

(*continued on page 181*)

Birmingham Centre

During February a display of old and modern light sources was arranged at the Birmingham Science Museum as part of the Golden Jubilee programme of the Birmingham Centre. During the four weeks of the exhibition it was visited by 24,000 people. In addition a number of lectures were given to parties of school children who visited the exhibition and other lectures were given at schools. The exhibition received wide publicity and was televised by the BBC.

Against a background of photographs of lighting installations of all kinds were shown a collection of electric lamps from the year 1880 and the types of shades and globes that were used with them. This led into a display of modern lamps including those for special applications. Also shown was part of the well-known George Herbert collection of ancient lamps which was on loan from the Benjamin Electric company.

When the exhibition closed many of the exhibits toured the showrooms of the Midlands Electricity Board.

Also as part of the Society's Golden Jubilee celebrations a lecture on "The Evolution of Light Sources," including numerous demonstrations was given on March 10th at Birmingham University by Dr. G. W. Sutton, Director of Siemens Edison Swan Ltd. Research Laboratories.

Opening his lecture, Dr. Sutton said that to place the evolution of electric light sources in their proper perspective it was necessary to look back 150 years. Sir Humphry Davy, in 1808, demonstrated to the Royal Institution the first arc-light. He had accumulated a "galvanic pile" of some 2,000 cells, to the terminal wires of which he attached two pieces of hard charcoal. Thus was born a source of illumination which still has its uses and from which was derived, at a much later date, a number of other arc-discharge sources of the greatest possible use to mankind.

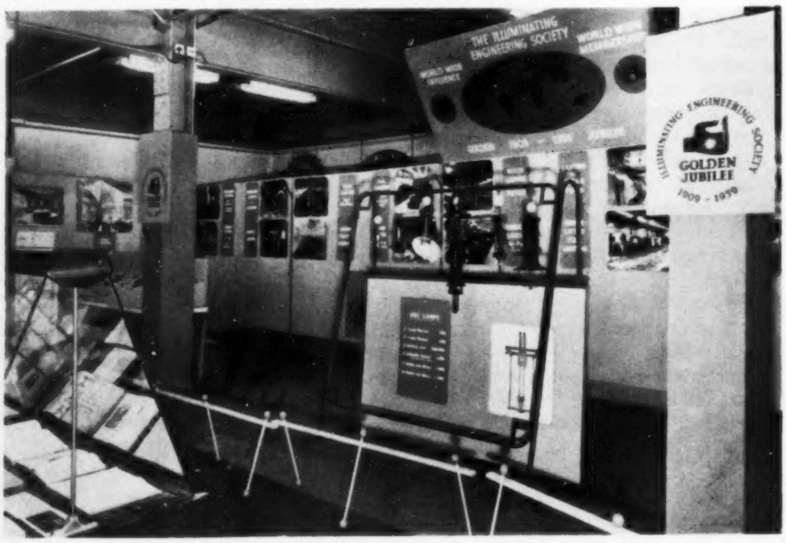
Invention of the mercury vacuum pump by Sprengel in 1865 and Crooke's work on high vacua, published in 1875, brought Swan's mind to the problem and made possible his achievement of 1878/9. His success was due to his realisation that the life of an incandescent carbon filament lamp was governed by the thoroughness with which the envelope is evacuated, and that it was necessary to heat the carbon filament during evacuation to drive off the last traces of gas and volatile material.

In 1910 Coolidge discovered a process of compressing, sintering and swaging tungsten powder and so producing the pure metal in a form in which it can be drawn down to extremely fine wire. This marked the beginning of the end of the carbon filament, particularly when Ervine Langmuir, following a line of thought that had been in the minds of lamp engineers for many years, produced a gas-filled bulb in 1911. These were the first lamps for which a "half-watt" rating was claimed. In 1913 Langmuir introduced gas-filled lamps, using an atmosphere of argon and a coiled filament that operated at 2,800°C, with a life of 1,000 hours and an efficiency of—in modern terms—12-15 lumens/watt. Finally, in the 1930's, krypton, which has a lower thermal conductivity, became sufficiently abundant to allow its use in certain special lamp classes. Dr. Sutton said that if tungsten lamps could be operated at the melting point of tungsten (3,655°C under normal conditions) by using a very high xenon pressure in the bulb the resulting colour would approach that of daylight and the efficiency would rise to some 55-60 lumens/watt. Spectacular advances have been made by following this idea and in particular a wide range of projection lamps is now available.

The first commercial hermetically sealed discharge lamps were those of Moore, who, in 1900, used nitrogen and carbon dioxide at low pressures and obtained soft golden-yellow light and a cold white light respectively at some 8 lumens/watt. The gases "cleaned up" in life, however, and these lamps became obsolete. When Claude in 1907 showed how to produce commercial quantities of neon and argon, these gases were employed in lamps of Moore's design, thus providing high voltage low-current devices that emitted the characteristic radiation of the gas filling at somewhat low luminous efficiency.

Xenon gas became more plentiful in 1945 and was found to give an even higher efficiency. Moreover the colour of the light emitted was very close to that of daylight. Thus by 1947 xenon arcs were available both for continuous and for pulse or flash operation and used as a flash-tube it is invaluable for high-speed photography. Since the xenon arc follows the applied voltage almost instantaneously, the shutter used in ordinary cinema projectors can be eliminated.

Views of the IES display of light sources at the Birmingham Science Museum. That below shows the George Herbert collection of ancient lamps.



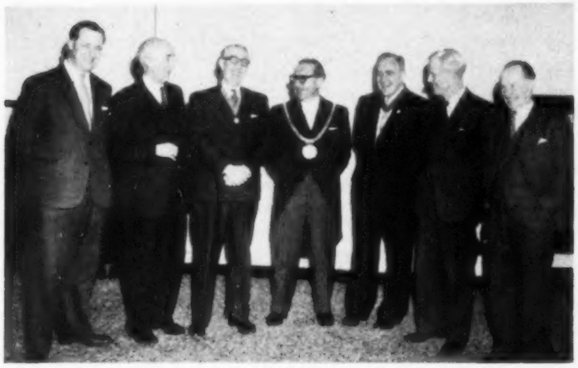
(*continued from page 179*)
and lighting could be justly proud of its achievements during the last few years. In dealing with the training of British architects he felt that young students were unable to devote sufficient time to the science of lighting and he hoped this would be remedied in the near future.

During the discussion that followed Mr. H. R. Ruff said he thought that there was a lack of sculpture in modern building designs, and that the architect relied on the lighting engineer to produce the contrast effects that hitherto had been part of the fabric. In his reply Mr. Penn Smith said this was substantially true as in its present phase, architecture tends to the severe and angular.

The vote of thanks was proposed by Mr. R. Sanders and received with acclamation by the audience.

Liverpool Centre

Sir Josiah Eccles, Deputy Chairman of the Electricity Council, was chief guest at the annual luncheon of the Liverpool Centre held at the Exchange Hotel, Liverpool, on March 2nd. Mr. Tom Jones, who presided, welcomed



At the Liverpool Centre annual lunch. Left to right Mr. J. S. Buck, Sir Josiah Eccles, Mr. Tom Jones (chairman), the Lord Mayor of Liverpool, the President, Mr. D. M. Kendon and Mr. N. Blackman.

many guests from other sections of the electrical industry. The Lord Mayor of Liverpool (Alderman H. Livermore) who replied to the toast to the city, congratulated Mr. C. C. Smith, city Lighting engineer on having been elected president of the IES.

Sir Josiah Eccles said that the power industry had set out to reduce the capital cost and improve efficiency of generating electricity. Thirty-six more 120 MW sets were being constructed; nine 200 MW sets were on order and the first was due in service this year; a further two 275 MW sets were ordered and one 550 MW set was under construction. The introduction of large generating sets gave British manufacturers experience which was most valuable in the export field.

The fast breeder reactor now being installed at Dounreay will yield valuable information which should lead to further economies. The fusion of hydrogen is a tantalising prospect largely because of the very high temperature which seems necessary to initiate and maintain reaction. If such temperatures could be produced, controlled and sustained safely in man-made vessels, it is probable that the energy requirements of humanity would be capable of being met for millions of years. It is known that gasses at very high temperatures are good conductors of electricity. If, then, a very hot gas is passed quickly at right angles to a magnetic field we have all the elements of an electrical generator. We have a magnetic field, an electrical conductor and relative movement all in the right relationship. Thus, it should be possible to create a potential difference using gas at right angles to the direction of movement and to the magnetic field. This has been done. The output is, of course, direct as distinct from alternating current.

Much further work, said Sir Josiah, is necessary, but the prospect of producing electricity without rotating generators is an attractive long term vision of those who are developing the process.

Leeds Centre

A special sessional meeting of the Leeds Centre was held on March 2nd when an invited audience enjoyed a paper entitled " Light from Phosphors " at the Leeds University. The paper, which was presented by Mr. H. R. Ruff and Mr. H. L. Privett, traced the known history of fluorescent and phosphorescent substances, with particular reference to the tremendous developments which have taken place in the past few years. Mr. Ruff held the close attention of the large audience throughout the paper whilst his assistants conjured up excellent demonstrations in very close succession.

The discussion, which was opened by Mr. D. Ebben, was of the same high standard as the paper, and in his replies to the questions, Mr. Ruff again demonstrated his complete mastery of the subject. Among the points arising was that in his opinion we have almost reached the peak luminous efficiency of 70 lm/w with the halophosphate group of phosphors, as predicted by Mr. Ruff in 1942. The improvement in lumen hours of modern fluorescent lamps is attributed to two factors—higher lumen output as a result of improved phosphors, and longer life due to improved cathode design. In reply to questions on the future of electro-luminescent panels, Mr. Ruff stated that although they were restricted at present to indicators or light-amplifying devices, they were also yielding valuable information on the behaviour of phosphors under certain conditions.

The vote of thanks was proposed by the Chairman, Dr. D. L. Smare.

FORTHCOMING EVENTS

LONDON

May 12th

Annual General Meeting. 5.15 p.m. Lecture, " Light and Pattern in Painting," by Sir Philip Hendy. 6.30 p.m. (At the National Gallery, Trafalgar Square, S.W.1.)

CENTRES AND GROUPS

May 7th

CARDIFF.—Open Forum on Lighting. (At the Demonstration Theatre, South Wales Electricity Board, The Hayes, Cardiff.) 6 p.m.

May 13th

LEEDS.—Visit to " Empress of Britain " at Liverpool and an address by F. W. Evans on the lighting of ships.

May 29th-30th

Joint Regional Conference of the Edinburgh, Glasgow and Newcastle Centres at Peebles.

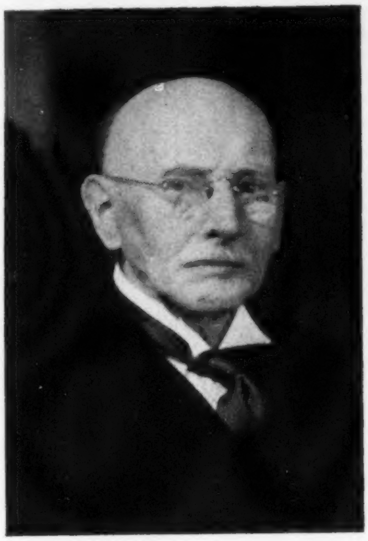
Joint Regional Conference of the Liverpool and Manchester Centres and the North Lancashire Group at Southport.

SUSTAINING MEMBERS OF THE ILLUMINATING ENGINEERING SOCIETY

The IES has played a major part in the development of better lighting. The following is a list of companies and organisations who show their appreciation of the work of the IES by being Sustaining Members of the Society.

A.E.I. Lamp and Lighting Co. Ltd.
Aladdin Lighting Ltd.
Allom Brothers Ltd.
Arrow Plastics Ltd.
Atlas Lighting Ltd.
Aurora Lamps Ltd.
Barlow and Young Ltd.
T. Beadle and Co. Ltd.
T. Beadle Export Co. Ltd.
Benjamin Electric Ltd.
City of Birmingham Education Department.
Bolton Corporation Lighting Department.
British Electrical Development Association.
British General Electric Co. (Pty.) Ltd., Johannesburg.
British Luma Co-operative Electric Lamp Society Ltd.
British Optical Association.
British Thomson-Houston Co. (S.A.) (Pty.) Ltd., Johanesburg.
Cartwright, J. T. and Sons, Ltd.
Chance Bros. and Co. Ltd.
The Cinematograph Exhibitors' Association of Great Britain and Ireland.
Claude Neon Lights of New Zealand Ltd.
E. Clegg and Sons Ltd.
Courtney, Pope (Electrical) Ltd.
Crompton Parkinson Ltd.
R. and A. G. Crossland Ltd.
Cryselco Ltd.
Richard Daleman Ltd.
George Davidson and Co. Ltd.
Hubert Davies and Co., Ltd., Johannesburg.
Dernier & Hamlyn Ltd.
Docker Bros.
Dominec (Pty.) Ltd., Johannesburg.
Dorman and Smith Ltd.
Downes and Davies Ltd.
Eastern Electricity Board.
Eastern Gas Board.
East Midlands Electricity Board.
Corporation of the City and Royal Burgh of Edinburgh.
E.G.S. Company Ltd.
Ekco-Ensign Electric Ltd.
Electric Lamp Industry Council.
Electric Street Lighting Apparatus Co. Ltd.
Electrical Components Ltd.
The Electricity Council.
George Ellison Ltd.
Engineering and Lighting Equipment Co. Ltd.
Erinoid Ltd.
Evans Electroselenium Ltd.
The Ever Ready Co. (Great Britain) Ltd.
Falk, Stadelmann and Co. Ltd.
Falks Electrical Supplies (S.A.) (Pty.) Ltd., Johannesburg.
H. W. Field and Son Ltd.
Foster Electrical Supplies Ltd.
B. French Ltd.
Fulford Brown Bros. (1929) Ltd.
Gas Council.
General Electric Co. Ltd.
G.P.O. (Engineering Department).
Girdlestone and Co. Ltd.
Donald Grant and Sons Ltd.
Hailwood and Ackroyd Ltd.
Harris & Sheldon (Electrical) Ltd.
Heyes and Co. Ltd.
S. H. Heywood and Co. Ltd.
Hirst, Ibbetson and Taylor Ltd.
Hivac Ltd.
Holland House Electrical Co. Ltd.
Holophane Ltd.
Hume, Atkins and Co. Ltd.
Imperial Chemical Industries Ltd. (Alkali Division).
Imperial Chemical Industries Ltd. (Metals Divison).
Imperial Chemical Industries Ltd. (Paints Division).
Imperial Chemical Industries Ltd. (Plastics Division).
Inductive Appliances Ltd.
J. A. Jobling and Co. Ltd.
James Kilpatrick and Son Ltd.
Knightshades Ltd.
Lancashire Dynamo Electronic Products Ltd.
Leeds Education Committee.
Linolite Ltd.
Littlewoods Pools, Central Maintenance Department.
Corporation of Liverpool.
London Electricity Board.
London Typographical Designers Ltd.
Joseph Lucas Ltd.
Lumenated Ceilings Ltd.
Luxram Electric Ltd.
Marryat and Place Ltd.
Merchant Adventurers Ltd.
Merseyside and North Wales Electricity Board.
Metallic Seamless Tube Co. Ltd.
Metropolitan-Vickers (S.A.) (Pty.) Ltd., Johannesburg.
Midland Electric Installation Co.
Midlands Electricity Board.
Morgan Crucible Co. Ltd.
Mortimer Gall and Co. Ltd.
Nettle Accessories Ltd.
New Era Lighting Industries (Pty.) Ltd., Johannesburg.
Newey and Eyre Ltd.
North-Eastern Electricity Board.
North-Western Electricity Board.
North-Western Gas Board (Liverpool Group).
Oldham Corporation Street Lighting Dept.
Oldham and Son Ltd.
Philips Electrical Ltd.
S. A. Philips (Pty.) Ltd., Johannesburg.
F. H. Pride Ltd.
Prudential Assurance Co. Ltd.
Albert E. Reed and Co. Ltd.
Revo Electric Co. Ltd.
Fred Reynolds Ltd.
John Riley and Son (Electrical) Ltd.
J. Rivlin Ltd.
Robinson, King and British Challenge Glazing Co. Ltd.
Rogers, G.S. (Pty.) Ltd., Johannesburg.
Rowlands Electrical Accessories Ltd.
Satchwell and Gittings Ltd.
James Scott and Co. Ltd.
Siemens Edison Swan Ltd.
Siemens Edison Swan (Pty.) Ltd., Johannesburg.
Sign Components Ltd.
Simplex Electric Co. Ltd.
S.L.R. Electric Ltd.
Herman Smith Smithlite Ltd.
Wm. Allan Smith and Co. Ltd.
W. H. Smith and Co. (Electrical Engineers) Ltd.
J. G. Sneath Ltd.
South-Eastern Electricity Board.
South of Scotland Electricity Board.
South Wales Electricity Board.
South-Western Electricity Board.
Southern Electricity Board.
Stella Lamp Co. Ltd.
Strand Electric and Engineering Co. Ltd.
Borough of Stretford.
Strong Electric Corporation (Great Britain) Ltd.
Superconcrete Pipes (S.A.) Ltd., Johannesburg.
Superior Manufacturing Development Co. (Pty.) Ltd.
Thermo-Plastics Ltd.
Thorn Electrical Industries (S.A.) Pty. Ltd., Johannesburg.
F. W. Thorpe Ltd.
Troughton and Young Ltd.
Tucker and Edgar (Teeanee) Ltd.
Walsall Conduits Ltd.
J. Walton (Electrical) Ltd.
Wardle Engineering Co. Ltd.
J. M. Webber and Co. Ltd.
Whitworth Electric Lamp Co. Ltd.
Wokingham Plastics Ltd.
A. J. Wright (Electrical) Ltd.
Yorkshire Electricity Board.

Obituary



Professor J. T. MacGregor-Morris

We regret to record the death on March 18th of one of the original members of The Illuminating Engineering Society and a familiar figure at its meetings from the beginning until only a few weeks before he died. John Turner MacGregor-Morris was born in 1872, the son of Dr. James Morris, and received his scientific education at University College, London. There he came under the influence of Ambrose Fleming.

In 1898 MacGregor-Morris moved to the People's Palace Technical Schools to organise classes in electrical engineering. The Schools developed into the East London College which in 1907 became a college (now Queen Mary College) of the University of London, with MacGregor-Morris as Head of the Electrical Engineering Department and a Professor of the University. This post he held until his retirement in 1938 when he was made a Professor Emeritus. He was a Fellow of both University College and Queen Mary College.

In the 1914-18 war MacGregor-Morris, in collaboration with A. F. Sykes, developed a submarine detector in the form of a sensitive directional hydrophone, but the work for which he is best known in lighting circles is the long series of researches on the carbon arc as a standard of light, work carried out under his inspiration by a succession of his pupils. A connected account of this work formed the subject of his Presidential address to the IES in 1940. He had previously been a member of Council and a vice-president and had served on many of the Society's committees.

Besides his numerous activities in The Illuminating Engineering Society, MacGregor-Morris was a keen member of the Institution of Electrical Engineers. On two occasions he was awarded a premium for a paper read before the Institution, in 1932 he gave the Faraday Lectures and in 1934-35 he was chairman of the Meter and Instrument Section.

MacGregor-Morris's principal recreation was music. In 1917 he married Annie Elizabeth Frances MacGregor who died in 1941. He will be long remembered by all who were privileged to know him. His kindly interest in the activities of others, his modesty and his integrity, rooted in firm religious convictions, endeared him, not only to his students, but to all who came into contact with him.

Correspondence

Gas street lighting

Dear Sir,—Further to the last item in "Lumeritas" Postscript in the March 1959 issue of *Light and Lighting*, the author may be interested in the following:—

Where the raw fuel from which both gas and electricity are derived is coal, as in Britain, there is not a great difference in the economies of street (or other) lighting by these two media. In some cases, for example in interiors, there may be secondary costs for redecoration, etc., which affect the issue, and amenity will, in many cases, affect the choice. However, where natural gas is available, as in parts of the United States of America and some other places, the economics tell a different story. Natural gas has usually about twice the calorific value of coal gas, and (with the addition of a suitable odorant) is immediately suitable for heating and illumination purposes, although modified burners are required. Hence the direct use of natural gas for lighting is considerably cheaper than its conversion to electricity in power stations at an overall efficiency of some 30 per cent. and subsequent use in that form. Secondary costs and amenity have to make a much stronger case to outweigh the economic considerations, and the existence or otherwise of a gas distribution becomes the prime consideration.

The recent experimental shipment of liquified (cooled) natural gas from the American continent to Britain is an illustration of the relative costs. If it can be utilised in Britain at a cost comparable to gas produced from indigenous coal, how much more economical must it be in the land of its origin ?

Once one has passed the stage of the incandescent tungsten lamp, gas can offer little or no rivalry to electricity in the quality of light, but at low fuel costs, gas may still put x lumens on the road surface at lower cost than electricity, if this is the major consideration. The fuel cost may easily be nil, or even negative, in areas where a producer of oil is faced with the necessity of disposing of occluded gas safely.

Herts. J. A. C. King.

Personal

Mr. D. Frith has been appointed as an assistant to Mr. J. T. Grundy, chief lighting sales engineer of Siemens Edison Swan Ltd.

Mr. John F. Roper has been appointed Regional Engineer of the British Lighting Council for the areas covered by the South Eastern and Southern Electricity Boards. He has had previous experience of this type of development work, for after joining the Lighting Service Bureau in 1946, he was responsible for its activities in Scotland from 1951 to 1953 when he returned to London in a senior position on the national staff, and for some time specialised on street and industrial lighting. He is already well known in the South of England where he has lectured widely.

Situations

Vacant

POSTSCRIPT By 'Lumeritas'

ONE of the new societies which have come into being since the last war is the Ergonomics Research Society. Readers may have noticed references in the national Press to this society on the occasion of its tenth anniversary meeting, which was held at Oxford early in April. The word "ergonomics" is derived quite respectably from two Greek words, the first meaning work or a man's employment, and the second meaning "of the laws." In this case the "laws" are the biological laws which need to be understood and observed if individuals are to work most efficiently and healthily. Among these laws are, of course, those relating to seeing, and so it follows that ergonomics (the descendant of the "scientific management" and "science of labour" of World War I vintage) is concerned with man's reactions to different conditions of lighting. The achievement of proper lighting is very obviously involved in "fitting the job to the worker," which is the avowed objective of the Ergonomics Research Society in seeking to advance the applied science of ergonomics.

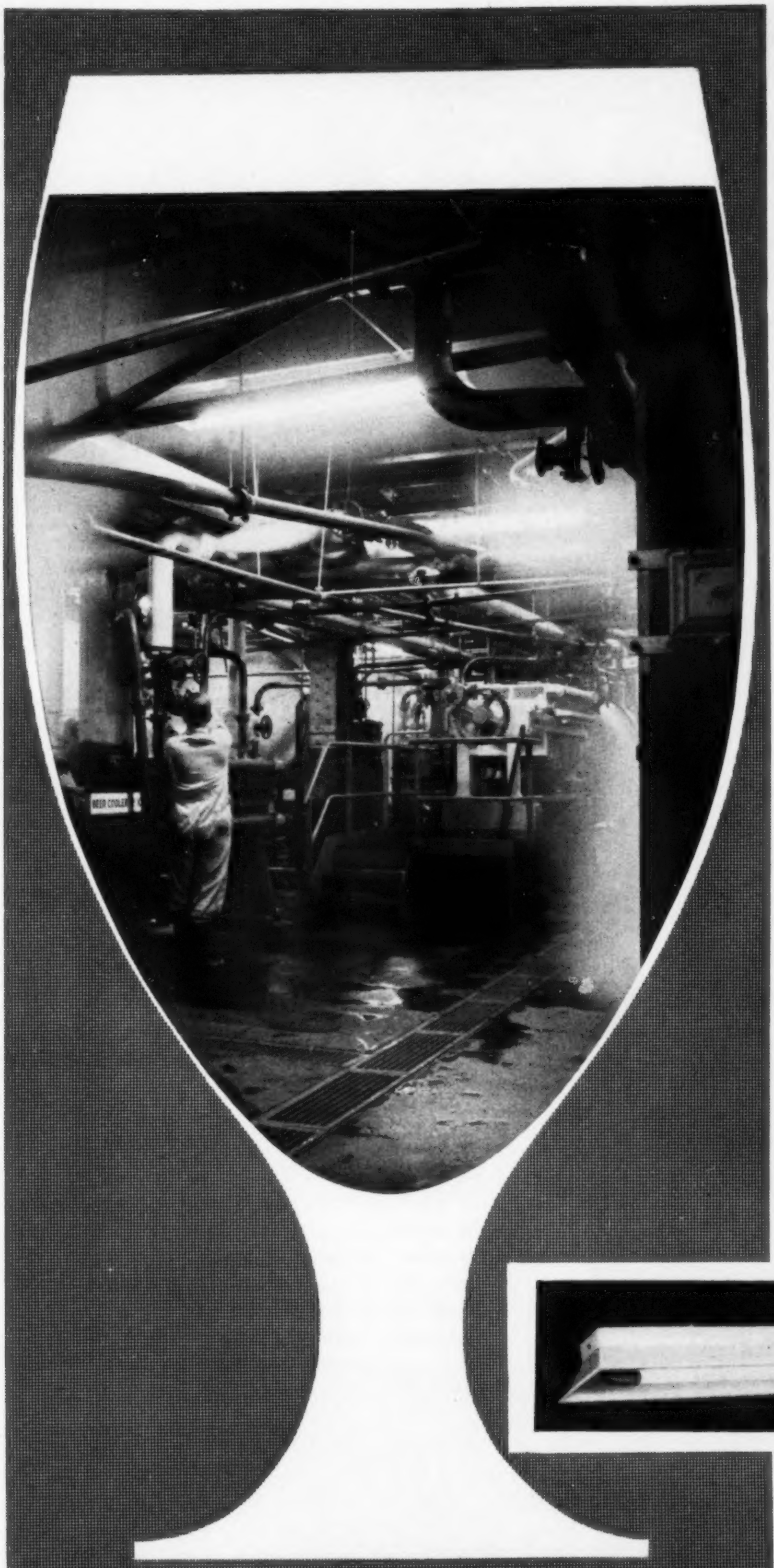
Yet another recently founded society—the British Occupational Hygiene Society—which concerns itself with the environmental conditions of the worker, is also clearly concerned with lighting. It has, in fact, recently held a symposium on occupational lighting and vision. These societies make a biological approach to the subject of lighting and, whilst this is also true of the IES, the engineering approach is the dominant one of our own society—as its name indicates. It is gratifying to know that there are other societies concerning themselves with the human aspects of lighting. Their activities may well accelerate the growth as well as the dissemination of knowledge which is needed for the development of better lighting practice.

HOWEVER, one of the difficulties in lighting practice is due to the fact that lighting cannot be wholly dissociated from its visible sources be they naked lamps, luminaires or illuminated structural surfaces. This is to say that what users judge is seldom the lighting itself—or perhaps I should say "the light"—but this together with its apparent sources. "The light" may be good from a functional standpoint but what is popularly meant by "the lighting" may be disagreeable because the installed sources part of it is disliked for one reason or another. Physiologists, as Lord Adrian has said, may be able to tell us how conditions of lighting affect our visual capacities but not necessarily what we shall like in the way of "lighting." Psychologists, who are more concerned to study how our likes and dislikes are determined, can tell us chiefly how diverse are the causes of our predelections and our antipathies, and that associations—either fortuitous or repeatedly renewed in daily life—bias many of our judgments. The present differences of opinion about the crystal chandeliers being tried in St. Paul's Cathedral—which I mentioned some months ago—are not really disagreements about the lighting but about the congruity of the luminaires, although Press comment on this matter has appeared under such headings as "Bright Light Controversy." As every lighting engineer knows, acceptance of installed lighting sometimes turns upon the appearance of the luminaires rather than upon the adequacy of the illumination and the suitability of the brightness distribution they provide. Even considerable glare is suffered gladly in some situations if the appearance of the glaring luminaires happens to be liked. There may, in fact, be nothing to choose between different, but well-planned, lighting installations so far as their "comfortability" and "revealing power" go, and the choice is made upon other considerations, of which appearance of the visible means of lighting is often one—though not the only one.

It is just as well that tastes differ in the matter of luminaires, otherwise a dull uniformity would be our lot. But we may as well recognise that, just as the styling of the frame in which spectacle lenses are mounted may make no difference to the optical aid the lenses afford, neither may the styling of the lamp containers used in lighting make any difference to the luminous aid the luminaires afford. So far as styling is concerned it is merely a matter of personal preference. The other features of different luminaires which make some preferable to others are not always appreciated by prospective buyers as they should be. I have already premised equality of luminous efficiency, but there remains quality of materials, durability, design for ease of installation and maintenance, and so on. I have not mentioned price because this is not a feature of a luminaire at all, although it may not be over-ridden by styling or any other attribute of the priced article.

IN reading the international review of lighting progress in last month's issue of this journal, I could not fail to notice the "tree-like" street lighting standard depicted on page 117. No doubt this caught the eye of most readers, not only because of its novelty but because the picture just happened to be the only one on the page. I must say I share the reviewer's doubt about the æsthetic merit of this "revolutionary pole design." However, it called to my mind what I think is a much more graceful, elegant and beautifully proportioned "tree-like" lighting standard which can be seen in the Bahnhofplatz at Lucerne. This standard has at the top a number of lanterns carried on a spray of symmetrically arranged curving branches. The height of the "trunk" is such that the branches and the "blossoms" they bear do not give the thing as a whole a top-heavy appearance. Incidentally, Continental practice in street lighting seems to me to be tending towards higher mounting than is our practice, and I think this is a good thing.

THERE are so many publications nowadays that one ought not to be very surprised on discovering a hitherto unknown one. Nevertheless, I was surprised recently to come across a reference to a periodical rejoicing in the title *Joy and Light*. However, the "light" is not the light of *Light and Lighting;* it is, apparently, an "inner light," and *Joy and Light* got itself into the news as the medium of publication of the annual report of the Lord's Day Observance Society.



THE SO 140/S ENCLOSED SODIUM LANTERN

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Bowater House, Knightsbridge. Architects: Guy Morgan and Partners. 8′x4′ recessed lighting fittings over public road. Centre panel of each is close reeded 'Perspex' 3/16″ thick. Surrounding panels are ·040 'Perspex'. Each fitting holds two 5′ 80 watt fluorescent lamps. The lay-lights are hinged for maintenance —'Perspex' being light enough to allow this. Set of amenity Lighting Columns with ·040 'Perspex' diffusers and continuous fittings with ·040 'Perspex' diffusers and black 'Perspex' ends under the low block in background. All fittings by Troughton and Young (Lighting) Ltd., Knightsbridge, London.

Amenity Lighting Columns with diffuser in ·040 'Perspex'. The fitting holds four 2 ft. 40 watt fluorescent lamps.

Continuous fittings between columns under low block, with diffuser in ·040 'Perspex' with black 'Perspex' ends. Each 5 ft. unit accommodates one 5 ft. 80 watt lamp.

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the British Lighting Council

The British Lighting Council has been formed to help all who are in any way concerned with electric lighting, and to encourage the proper use of light in all its diverse applications to the ultimate benefit of the consumer in greater production, improved welfare, increased safety, and more agreeable leisure hours. The Council is supported equally by electricity boards, and the manufacturers of lamps and fittings.

It provides an advisory service for anyone who requires it—any architect, any consultant, any electrical trader, who has a lighting problem is invited to contact or preferably visit the B.L.C. *if possible with his client* and discuss matters in general terms. The staff is always anxious to help in every way save in the preparation of a detailed scheme, for which supporting members of the Council are fully equipped.

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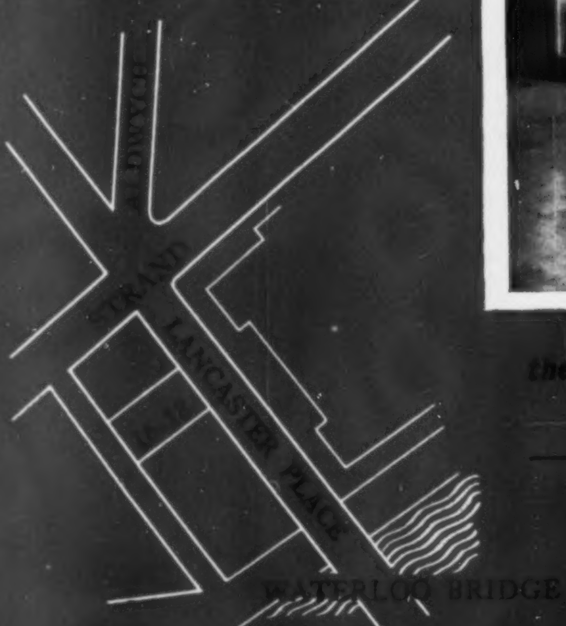

above: *A general view of the new centre, including one of the demonstration windows in the Shop section, the illuminated fireplace, with its transparent mirror, in the Domestic section, and at higher level part of the cornice comparing the effects of the six standard colours of fluorescent tube.*